JPRS-JST-89-025
6 NOVEMBER 1989

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DIE CAM SYSTEM FUNCTION SPECIFICATIONS

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DIE CAM SYSTEM FUNCTION SPECIFICATIONS

94291257 Tsukuba KANEGATA CAM SHISUTEMU NO KINO SHIYO in Japanese, Oct 88, pp 1-62

[Book by Hiroshi Sekiguchi and Kuniko Inoue: CAD/CAM Research Group, Machinery & Metals Committee, Industrial Technology Coordinating Council; Publication No. 88 of Mechanical Engineering Laboratory]

CONTENTS

Forward

In this publication we follow up the previously issued report "Die CAD System Function Specifications" with a further discussion of the function specifications and processing procedures for a die-oriented CAM system. Much developmental work is being done today on CAD/CAM systems. The emphasis tends always to favor CAD systems, however, with not enough studies done in the area of CAM system development.

This being so, we took the data output from the "Die CAD System" [report], systematized the data necessary for die manufacture, broke these data down into the categories of processing, assembly, and inspection, and extracted the functions for procedure design, job design, and simulation in each category. We classified the information deemed necessary in each process, and clearly identified which functions were applicable for the input data, control data, reference data, and output data (i.e. processing results). By so doing, we sought to get a better grip on the software technology involved in CAM systems. By pursuing these future ideals for function specifications, the tasks necessary for developing a CAM system should be clearly identified, and the development of CAM systems for manufacturing machines in general, besides dies, ought to become possible.

This research was carried on as part of the activities of the Machinery & Metals Committee and Machine Subcommittee of the Industrial Technology Coordinating Council, Agency of Industrial Science and Technology.

In the Machine Subcommittee, a CAD/CAM research group was formed in the fall of 1982, over 5 years ago. The main function of this research group was to exchange information pertaining to CAD/CAM technology and research. In order to further raise the mutual technological levels of the participating technicians, research conferences were held semiannually, and working groups were organized, both in regional blocks throughout the country, and based in the public testing and research facilities in the Kanto and Chubu areas. These working groups were set up for the purpose of studying CAD/CAM systems and exchanging information relative thereto. Following the publication of the report entitled "Die CAD Systems," research work began in November, 1985, for "Die CAM System Function Specifications."

It would be beneficial, at this point, to draft consistent function specifications for the design and manufacture of dies. In view of the difficulties currently encountered in die CAM system development, however, the specifications need to be put together as quickly as possible. Thereupon, we have formulated function specifications for processing, assembly, and inspection, in ideal terms.

We invite constructive criticism regarding this research from a wide range of fields, and will be most gratified if this report contributes to the knowledge of those working or interested in CAD/CAM systems and production software.

Listed below are the research organizations which participated in this research or in the writing of this report, including those connected with the Industrial Technology Coordinating Council, the Machinery & Metals Committee, the Machine Subcommittee, and the CAD/CAM Research Group working groups.

Testing & Research Organizations

(Organizations participating in the working groups or blocks)

- Hokkaido Prefectural Industrial Testing Station
- Iwate Prefectural Industrial Testing Station
- Ibaraki Prefectural Industrial Technology Center
- Tochigi Prefectural Industrial Technology Center
- Gunma Prefectural Industrial Testing Station
- Saitama Prefectural Casting Machine Industrial Testing Station
- Saitama Prefectural Industrial Technology Research Institute
- Chiba Prefectural Machinery & Metals Testing Station
- Tokyo Metropolitan Industrial Technology Center
- Kanagawa Prefectural Industrial Testing Station
- Nagano Prefectural Precision Industrial Testing Station
- Shizuoka Prefectural Industrial Technology Center
- Aichi Prefectural Industrial Technology Center
- Nagoya Municipal Industrial Research Institute
- Gifu Prefectural Metals Testing Station
- Gifu Prefectural Industrial Technology Center
- Ishikawa Prefectural Industrial Testing Station
- Fukui Prefectural Industrial Technology Center
- Osaka Metropolitan General Research Institute for Industrial Technology
- Okayama Prefectural Industrial Technology Center
- Hiroshima Prefectural Industrial Technology Center, Western Division
- Hiroshima Prefectural Industrial Technology Center, Eastern Division
- Hiroshima Municipal Industrial Technology Center
- Yamaguchi Prefectural Commercial & Industrial Guidance Center

1. RESEARCH BACKGROUND, OBJECTIVES

1.1 Research Background

It is impossible to talk about our high-tech society without talking about the computer. NHK, some time back, aired a three-night documentary on the computer entitled "Japan in The Global Context." This was in November, 1987. This series of programs dealt with the leading edge of world computer development and the impact of computer advances on society. Among the topics covered were the remarkable data-gathering operations of the U.S. database industry, the assault on international language barriers that started with the Japanese word processors, supercomputer-based hypersonic jetliner wind-tunnel simulation, and the state of Japan's ICOT knowledge-base machine development. We may expect computers to have an increasingly deep influence on human society.

The Science & Technology Agency conducts a "Technology Prediction Survey" every 5 years in an effort to formulate a medium- to long-range outlook on technological development.[1.1] A report has now been issued on the fourth of these surveys. Using the Delphi method, a questionnaire was sent to over 2000 specialists, asking them to make predictions in 1,071 categories covering 17 fields for the next 30 years. According to the results, in the fields of information, electronics, and software, advances in software testing will lead to radically shorter software development times (by 2002), and inference-capable 5'th-generation computers will be implemented (by 1996). In the fields of production and labor, engineering databases will be built which systemize process technologies (by 2003), the MAP and TOP production system protocols will be finalized and put into service (1994), and robots will be developed to detect and correct malfunctions in unmanned factories (by 2002). The predictions in these fields are thought to have a high probability of fulfillment. Thus we may expect to see the realization of highly automated unmanned production systems by the end of this century and the beginning of the next.

In the manufacturing industries, wide-ranging computer support systems are now being talked about, with the introduction of CAD/CAM as configurational elements, as is seen in implementations of FA and CIM. So-called "regional system technological development" began to be implemented by the Agency of Small and Medium Enterprises in the mid-1980's, and computer-based systemization has become a powerful regional trend, like it or not. Industry, government, and academia are now cooperating more closely to enhance systemization in small and medium-sized businesses. If we consider CAD/CAM technology, in this context, as an elemental technology in industrial systemization, we wind up questioning how conclusive this element is. The CAM side of this is closely related to production systems, however, so we will probably aim at the growth of these technologies in a mutually coordinated way. In the research group, we decided to focus on the function specifications of CAM for metal dies, the latter representing a typical example of individual production.

We already discussed the reasons for selecting die CAD/CAM systems as the subject of our research in the previously published report "Die CAD System Function Specifications."[1.2] That report pertained to die CAD, and did not deal with CAM. Subsequently the question of what to make the next research subject was discussed in the working group. The following three things were decided at the seventh meeting of the research group in November, 1985.

1) CAD has already been reported on, so the emphasis will now be placed on finishing a CAD/CAM study at the same level.

2) Nearly all commercially available CAD/CAM systems emphasize CAD, so what is needed now is to enhance the CAM functions, including procedure design and the like.

3) By narrowing the CAM study focus to dies, it will be possible to image out the production facilities and methods, to some extent, making it easier to organize the work.

Most dies, however, are made for single-item production, involving many complex shapes which include freely curved surfaces. In the view of some, therefore, this involves a very specialized production method. We came to the conclusion, however, that die production, while certainly exhibiting these peculiarities, nevertheless involves a wealth of processing/machining technology and procedures which are common to many machine components. We believe, therefore, that our findings on die CAM systems will be valuable for other machine component production systems.

1.2 Research Objectives

In our work on die CAD systems, we sought to come up with the ideal CAD system. If in like manner we seek to define a die CAM system so that it has a consistent content as a CAD/CAM system, then we should naturally arrive at a clear picture of what the future CAM system will be. As we began our work, we were aware of the close relationship between CAM and any die production system, so, keeping FA (factory automation) and CIM (computer-integrated manufacturing) clearly in view, we came up with the following two guidelines, giving due consideration to information and material flows.

1) Our research would cover everything up to the preparatory manufacturing stages for processing/machining, assembly, and inspection, but would not deal with the actual processing/machining procedures themselves.

2) Our research would not deal with such production management operations as production planning or procedure control.

In carrying on this research, as when doing the die CAD system research, we held meetings several times a year, making it necessary to limit our scope to die CAM. By formulating a clear picture of future die CAD/CAM systems, however, we have sought to isolate development tasks and problems, and to identify relationships with peripheral and related technologies. We also think that we have dispelled some of the mist that has shrouded predictions of when such a system will be realized.

References

1.1 Science & Technology Agency: *Nippon no Mirai Gijutsu '87*, Shukan Daiyamondo special issue, Nov 87

1.2 Inoue, *et al.*: *Kanegata CAD Shisutemu no Kino Shiyo*, Mechanical Engineering Laboratory document, vol 77, Mar 85

2. DIE PRODUCTION PROCESSES & CAM SYSTEM

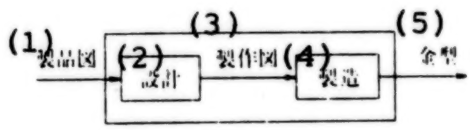
We here discuss briefly the positioning of CAM systems in die production processes, and the way in which CAM-system function specifications will be represented.

2.1 Die CAM System

A die is a molding tool which creates shapes by means of a transfer process. Dies are well-suited to mass-production operations. As die-making processes have become more automated in recent years, dies have increasingly come to be used also in small-lot production operations.

In this report, we will use the designation "die manufacturing processes" to mean all of the procedures involved in the production of dies. This being the case, the input into the die manufacturing processes will be the data describing the products to be molded, and the output will be the dies. As is diagrammed in Figure 2.1, these processes can be broadly divided between (1) those procedures which involve the data needed to make the dies, i.e. the procedures which lead up to the preparation of the fabrication drawings, and (2) the procedures involved in the actual production of the dies based on the said drawings. The former procedures are commonly referred to as "design," and the latter as "fabrication." We have already dealt with the design procedures in the previous report "Die CAD System Function Specifications." This report pertains to the latter procedures, namely those involved in fabrication. Die fabrication drawings are output from the design stage and input into the fabrication stage.

Figure 2.1 Die Manufacturing Processes



Key:

1. Product diagram or drawing
2. Design
3. Fabrication diagram or drawing
4. Fabrication
5. Die

During fabrication, the dies and the information pertaining to their fabrication are both processed in order, maintaining their respective relationships. The fabrication procedures may be divided into processing (including machining), assembly, and inspection, each of which procedures may in turn be further broken down into procedure design, job design, and simulation. As diagrammed in Figure 2.2, there are two ways of understanding and representing the flow of fabrication-related data, namely horizontally and vertically. We have adopted the vertical approach.

The primary purpose of automating this fabrication-related data processing is to provide added support to the technicians involved in the fabrication. It is therefore extremely important that we clearly identify those functions which a CAM system should have in order to implement such automation.

Figure 2.2 Fabrication-Related Data Processing

Key:

1. Processing/machining procedure design
2. Processing/machining job design
3. Processing/machining simulation
4. Assembly procedure design
5. Assembly job design
6. Assembly simulation
7. Inspection procedure design
8. Inspection job design
9. Inspection simulation

2.2 Function Specification Representation

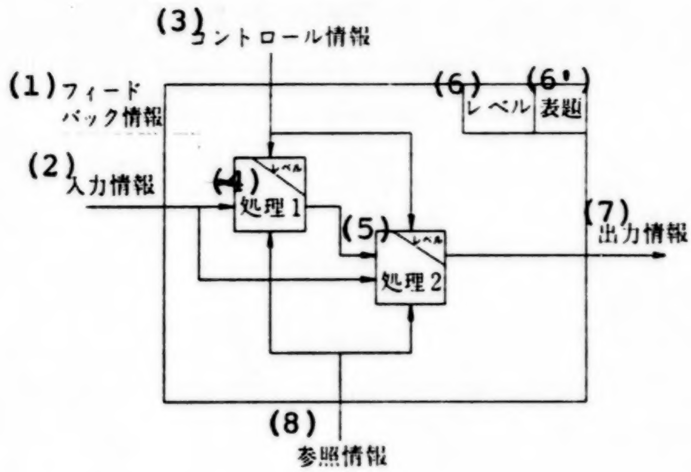
This report is a continuation of our previous report. In devising the CAM-system function specifications, we use herein the same method of representation as was used in the previous report. This method follows the SADT provisions, and was explained in detail in the previous report. We will briefly cover here the representation rules necessary to understanding the function specifications.

Function specifications are represented as process and data flows, diagrams of which are detailed hierarchically. The method of representation is diagrammed in Figure 2.3, in which blocks depict processes and directional lines indicate data flows. At the upper right-hand corner of the figure are noted the process hierarchy level and a designation of the process content. Inside each block is represented the course of a one-stage-detailed process.

The input data consist of data coming into the blocks from the left via solid directional lines and feedback data via dotted lines. Control data are represented as coming into the blocks via solid directional lines from above, while reference data come from below via directional lines. Output data are represented as flowing to the right via solid directional lines. The control data determine the process flow, and in general pertain to evaluation criteria. Reference data consist of standardized data, such as that pertaining to JIS standards. Feedback data are derived from the output results produced by subsequent processes.

By connecting data flows with directional lines, it is possible to represent the sequential relationships pertaining to how the data are processed, and to preclude any data losses or excesses that might arise from detailing.

Figure 2.3 Function Specification Representation



Key:

1. Feedback data
2. Input data
3. Control data
4. Process 1 \ Level
5. Process 2 \ Level
6. Level
6'. Designation
7. Output data
8. Reference data

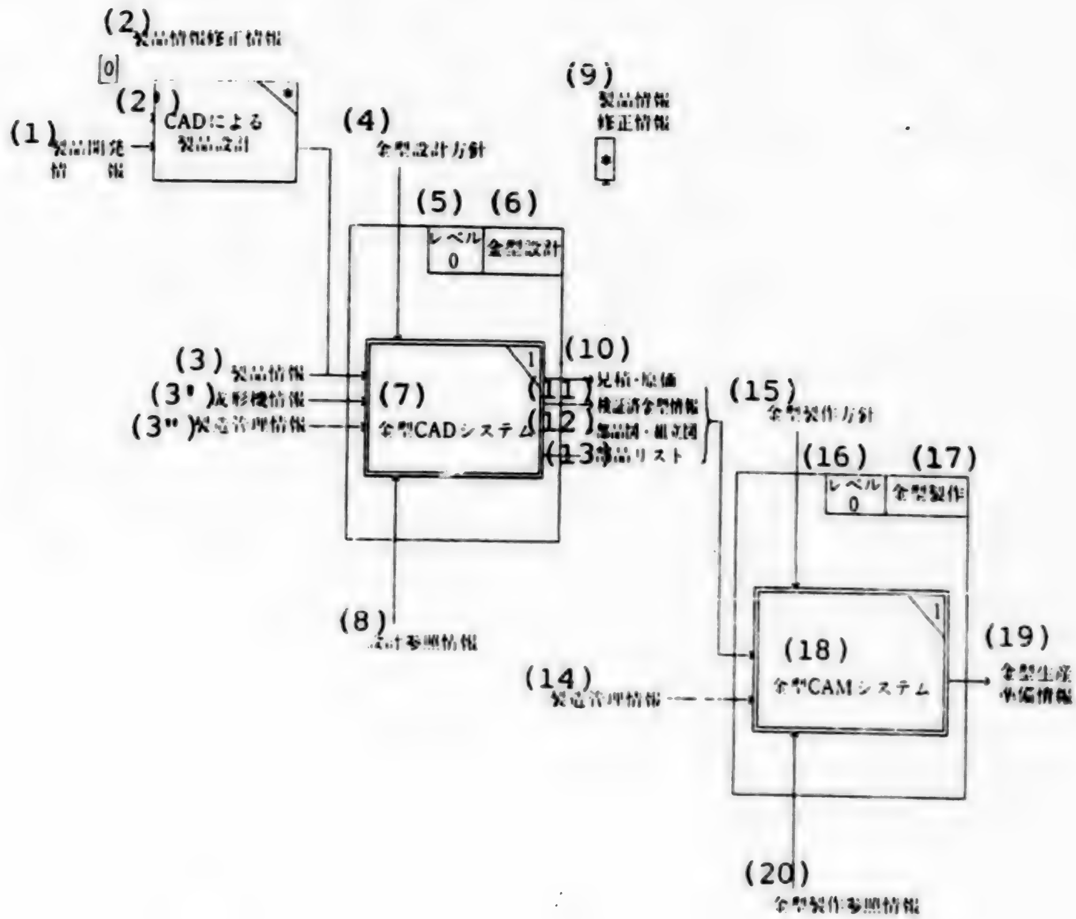
3. FUNCTION SPECIFICATIONS FOR DIE CAM SYSTEMS

3.1 Die Fabrication (Level 0)

This system is for two types of dies, namely injection molding dies and press dies. In Figure 3.1 is given a diagram showing the input data and final output data in a CAM system for these types of dies.

In die fabrication, the input data consist of product and assembly diagrams output from the die design operation (CAD system), parts lists, data on fully-tested dies, estimate and cost data, and production control data (pertaining to die processing machines, delivery dates, production costs, etc.). While referencing the die fabrication reference data, and following the die fabrication guidelines, the system outputs preparatory die-production data.

Figure 3.1   Die Fabrication (Level 0)



Key:

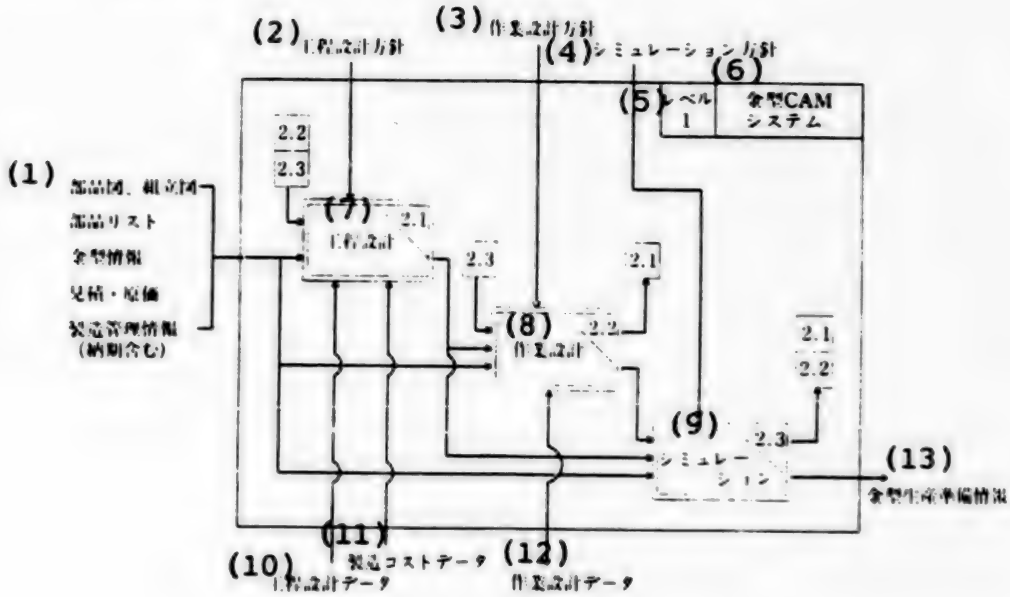
1. Product development data	2. Product-data correcting data
2'. CAD-based product design	3. Product data
3'. Molding machine data	3". Production control data
4. Die design guidelines	5. Level 0
6. Die design	7. Die CAD system
8. Design reference data	9. Product-data correcting data
10 Estimate, cost data	11. Fully-tested die data
12 Parts drawings, assembly diagrams	13. Parts lists
14. Production control data	15. Die fabrication guidelines
16. Level 0	17. Die fabrication
18. Die CAM system	19. Preparatory die production data
20. Die-fabrication reference data	

In the ideal system, the data required for die production are prepared in thoroughgoing computer-based simulation operations prior to the start of

actual work. With conventional die fabrication methods, correction procedures need to be performed after fabrication, but that step would either be made unnecessary or only infrequently necessary with the ideal system.

3.2 Die CAM System (Level 1)

Figure 3.2 Die CAM System (Level 1)



Key:

1. Parts drawings, assembly diagrams, parts lists, die data, estimates and costs, production control data (including delivery dates)
2. Procedure design guidelines
3. Job design guidelines
4. Simulation guidelines
5. Level 1
6. Die CAM system
7. Procedure design
8. Job design
9. Simulation
10. Procedure design data
11. Production cost data
12. Job design data
13. Preparatory die production data

A die CAM system, as is diagrammed in Figure 3.2, is made up of processing units which perform procedure design, job design, and simulation. One approach to performing the processes is to make classifications, from the job mode, of processing/machining, assembly, and inspection. If computer support is to be provided, however, it is advantageous to use the method shown in the diagram which permits the application of standardized processing procedures, so that method was adopted here.

(1) In the procedure design (level 2.1), parts drawings, assembly diagrams, parts lists, die data, estimate and cost data, and production management data (including delivery times) are made the input data. Then, while referencing the production cost data and procedure design data for each job (i.e. processing/machining, assembly, and inspection), the procedure data is output, in accord with the procedure design guidelines. Correctional data may also be fed back in to the system, depending on the results of the level 2.2 job design and level 2.3 simulation. Economy-related evaluation criteria are used as the procedure design guidelines, and equipment/instrument data for processing/machining, assembly, and inspection are employed as reference data.

(2) In the job design (level 2.2), the procedure data for each job output from level 2.1 are made the input data, and job design data and production cost data are used as reference information. Job data are then output, in accordance with the job design guidelines. Correctional data may also in some cases be fed back into the level-2.1 procedure design operation. Economy-related evaluation criteria are used as the job design guidelines, and the jig and tool data for each piece of equipment are used as the reference data.

(3) In the simulation (level 2.3), the job data for each job output in level-2.2 is made the input data. Then, following the simulation guidelines, preparatory production data is output for fully tested processing/machining, assembly, and inspection. In some cases correctional data are also fed back to the level-2.1 procedure design or level-2.2 job design operations. The simulation guidelines determine which operation the feedback data are directed to. Evaluation criteria for functionality and economy are employed as the evaluation guidelines.

3.3 Die CAM (Level-1 Detailing)

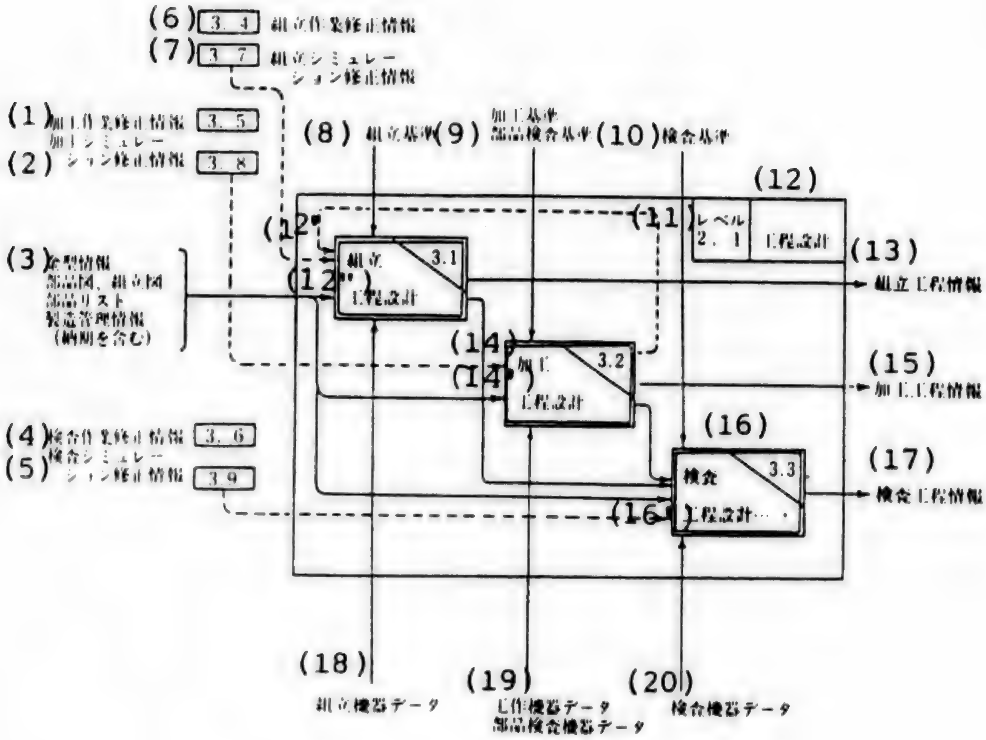
3.3.1 Procedure Design (Level 2.1)

Procedure design for dies is made up, as is diagrammed in Figure 3.3, of processing units for performing assembly procedure design, processing/machining procedure design, and inspection procedure design.

(1) In the assembly procedure design (level 3.1), die data, parts drawings, assembly diagrams, parts lists, and production control data (including delivery times) are made the input data, and assembly procedure data are output. In this operation, the assembly guidelines, assembly procedure design guidelines, and other assembly criteria are followed, while referencing such assembly equipment data as standard parts, standard assembly methods, and robot information.

The order in which the dies are assembled is determined in this process, as are the equipment, jigs, and tools which will be used in the assembly. Then, based on this, the assembly order list and information on the equipment, jigs, and tools used in the assembly are output.

Figure 3.3 Procedure Design



Key:

1. Processing/machining job correctional data
2. Processing/machining simulation correctional data
3. Die data, parts drawings, assembly diagrams, parts lists, production control data (including delivery dates)
4. Inspection job correctional data
5. Inspection simulation correctional data
6. Assembly job correctional data
7. Assembly simulation correctional data
8. Assembly criteria
9. Processing/machining criteria
   Parts inspection criteria
10. Inspection criteria
11. Level 2.1
12. Procedure design
12'. Assembly
12". Procedure design
13. Assembly procedure data
14. Processing/machining
14'. Procedure design
15. Process/machining procedure data
16. Inspection
16'. Procedure design
17. Inspection procedure data
18. Assembly equipment data
19. Machine tool data, parts inspection instrument data
20. Inspection instrument data

Correctional data are also fed back, depending on the results of the level-3.4 assembly job design and level-3.7 assembly simulation.

(2) In the processing/machining procedure design (level 3.2), die data, parts drawings, assembly diagrams, parts lists, production control data (including delivery dates), and assembly procedure data are made the input data, and processing/machining procedure data are output. In this operation, processing/machining criteria and parts inspection criteria are followed, while machine tool data and parts inspection instrument data are referenced.

It is in this process that the shape and size of the stock material on which the processing/machining is to be performed are determined, and that the processing/machining methods, processing/machining sequences, and heat-treatment methods are determined. The processing/machining machinery to be used is also determined, according to the processing/machining method, and the attachment hardware and jigs are designed. Based on these determinations and designs, the stock material shapes, processing/machining sequences, machine tools to be used, and jig specifications are output.

Correctional data may also be fed back in, depending on the results of the level-3.5 processing/machining job design and level-3.8 processing/machining procedure simulation.

(3) In the inspection procedure design (level 3.3), the input data used are die data, parts drawings, assembly diagrams, parts lists, production control data (including delivery dates), assembly procedure data, and processing/machining procedure data, and inspection procedure data are output. In this operation, inspection criteria are followed, and reference is made to inspection standards, technical inspection data, inspection instrument control data, and inspection instrument data.

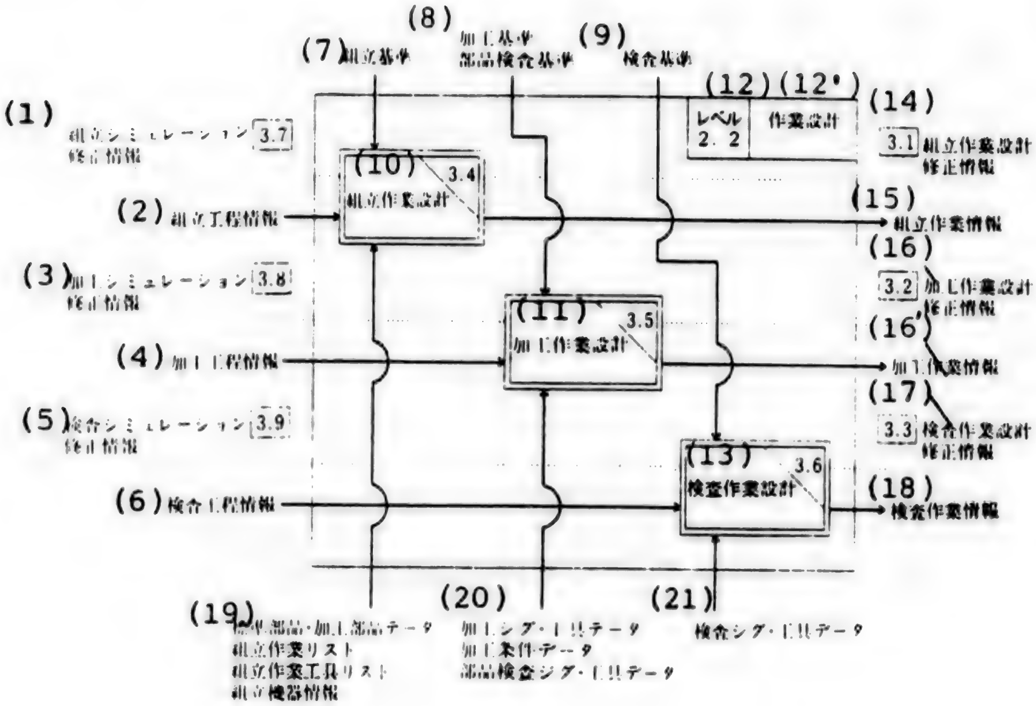
In this process, the inspection items and inspection conditions are extracted and the inspection sequences and inspection methods determined. Also determined are the inspection equipment to be used. Based on these determinations, the inspection items, inspection methods, inspection instruments to be used, inspection sequences, and inspection conditions are output.

Correctional data are also fed back in, depending on the results of the level-3.6 inspection job design and level-3.9 inspection procedure simulation.

3.3.2 Job Design (Level 2.2)

Die job design is made up, as is diagrammed in Figure 3.4, of processing units which perform assembly job design, processing/machining job design, and inspection job design.

Figure 3.4 Job Design (Level 2.2)



Key:

1. Assembly simulation correctional data
2. Assembly procedure data
3. Processing/machining simulation correctional data
4. Processing/machining procedure data
5. Inspection simulation correctional data
6. Inspection procedure data
7. Assembly criteria
8. Processing/machining criteria, parts inspection criteria
9. Inspection criteria
10. Assembly job design
11. Processing/machining job design
12. Level 2.2

12'. Job design

13. Inspection job design
14. Assembly job design correctional data
15. Assembly job data
16. Processing/machining job design correctional data

16'. Processing/machining job data

17. Inspection job design correctional data
18. Inspection job data
19. Standard parts & processing/machining parts data, assembly job list, assembly job tool list, assembly equipment data

20. Processing/machining jig & tool data, processing/machining condition data, parts inspection jig & tool data
21. Inspection jig & tool data

(1) In the assembly job design (level 3.4), die data (including parts drawings, assembly diagrams, parts lists) and the assembly procedure data output in level 2.1 are made the input data, and assembly job design specifications are output. In this operation, assembly job design criteria and assembly condition selection criteria are followed, and reference is made to standard parts and machined parts data, assembly job lists, assembly job tools lists, and assembly equipment data. It is in this process that the assembly job sequences are determined. The assembly conditions are also determined, following the assembly condition selection criteria. Control programs are output for the assembly equipment. Should anything untoward occur in the assembly design operation, correctional feedback data are directed to level 3.2.

(2) In the processing/machining job design (level 3.5), die data (including parts drawings, assembly diagrams, and parts lists) and processing/machining procedure data are made the input data, and processing/machining job design is performed, following processing/machining criteria and parts inspection criteria, and making reference to processing/machining jig and tool data, processing/machining condition data, and data on jigs and tools used to inspect the parts.

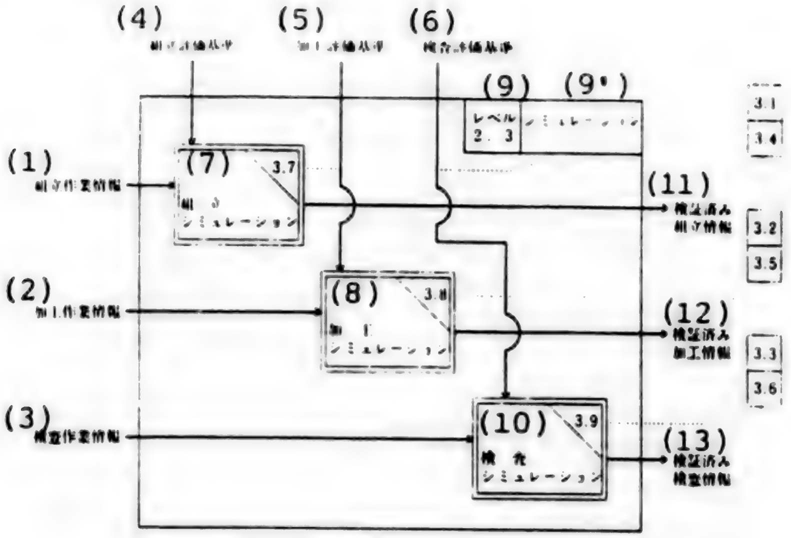
In this process, the job methods and job sequences are first determined, then the processing/machining tools, followed by the processing/machining conditions, after which the tool paths are worked out and NC programs are created. Correctional data are also fed back in, depending on the results of the level-3.8 processing/machining simulation.

(3) In the inspection job design (level 3.6), die data (including parts drawings, assembly diagrams, and parts lists) and inspection procedure data are made the input data. Following the inspection criteria and making reference to the inspection jig and tool data, inspection job design is performed.

In this process, the input data consist of such inspection procedure data as inspection items, inspection locations, inspection instruments, inspection methods, inspection steps, and inspection conditions. Inspection job steps are determined. Then the measurement probes and holders for the automatic inspection instruments are determined, and control data for the automatic inspection instruments are created and output. Should any problems arise in the inspection job design operation, correctional feedback data is output and directed to the inspection procedure design operation (level 3.3).

Simulation, as is diagrammed in Figure 3.5, is made up of processing units that perform assembly, processing/machining, and inspection simulation, respectively.

Figure 3.5   Simulation (Level 2.3)



Key:

1. Assembly job data
2. Processing/machining job data
3. Inspection job data
4. Assembly evaluation criteria
5. Processing/machining evaluation criteria
6. Inspection evaluation criteria
7. Assembly simulation
8. Processing/machining simulation
9. Level 2.3

9'. Simulation

10. Inspection simulation
11. Fully tested assembly data
12. Fully tested processing/machining data
13. Fully tested inspection data

(1) In assembly simulation (level 3.7), assembly job data are input, and the assembly equipment movement and assembly job routes are simulated, following the assembly evaluation criteria. The correctness of the assembly job is also verified, assembly costs are evaluated, and fully tested assembly data are output. Depending on the simulation results, feedback data may also be output and directed to the assembly procedure design (level 3.1) and assembly job design (level 3.4) operations.

(2) In processing/machining simulation (level 3.8), processing/machining job data are input, the machine and system actions are checked and machining precision is simulated, following the processing/machining evaluation criteria. The correctness of the machining methods are verified, machining costs are evaluated, and fully tested machining data are output. Depending on the results of this simulation, feedback data are output and directed to the processing/machining procedure design (level 3.2) and processing/machining job design (level 3.5) operations.

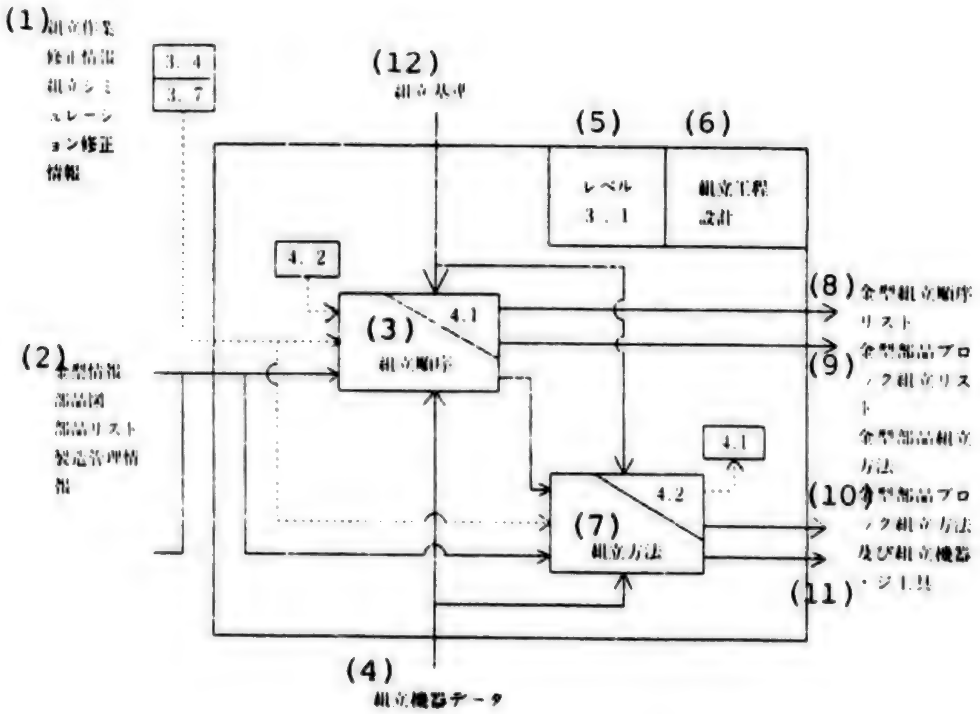
(3) In inspection simulation (level 3.9), inspection job data are input, and, following the inspection evaluation criteria, the action of the automatic inspection instruments is checked, the correctness of the inspection methods is verified, inspection costs are evaluated, and fully verified inspection data are output. Depending on the results of this simulation, feedback data are output and directed to the inspection procedure design (level 3.3) and inspection job design (level 3.6) operations.

3.4 Procedure Design (Level 2.1) Detailing

3.4.1 Assembly Procedure Design (Level 3.1)

Assembly procedure design, as is diagrammed in Figure 3.6, is made up of processing units which determine the assembly sequences and assembly methods.

Figure 3.6 Assembly Procedure Design (Level 3.1)



Key:

1. Assembly job correctional data, assembly simulation correctional data
2. Die data, parts drawings, parts lists, production control data
3. Assembly sequence
4. Assembly equipment data
5. Level 3.1
6. Assembly procedure design
7. Assembly method
8. Die assembly sequence list
9. Die parts block assembly list
10. Die parts block assembly method
11. Assembly equipment, jigs, tools
12. Assembly criteria

(1) Assembly Sequence Determination (Level 4.1)

(Input)

Die data (type, configuration, cooling method)
Parts drawings (drawings of all the die parts)
Assembly diagrams (Assembly diagrams for all parts)
Parts lists (lists of all parts)
Production control data

(Output)

Die assembly sequence lists
Die parts block assembly lists

(Reference Data)

Assembly equipment data (data pertaining to assembly of assembly equipment)

(Control Data)

Assembly criteria (parts, block assembly criteria)

(Processing)

In this operation, the die assembly sequences are determined from the die data, parts drawings, assembly diagrams, parts lists, production control data, and processing/machining procedure data.

Correctional data may be fed back, depending on the results of the processing/machining procedure(s), assembly job(s), and assembly simulation.

(2) Assembly Method Determination (Level 4.2)

(Input)

Die assembly sequence lists
Die parts block assembly lists
Die data (type, configuration, cooling method)
Parts drawings (drawings of all die parts)
Assembly diagrams (assembly diagrams for all parts)
Parts lists (lists for all parts)
Production control data

(Output)

Die parts assembly methods
Die parts block assembly methods and assembly equipment, jigs, and tools

(Reference Data)

Assembly equipment data (data pertaining to assembly of assembly equipment)

(Control Data)

Assembly criteria data (parts, block assembly criteria)

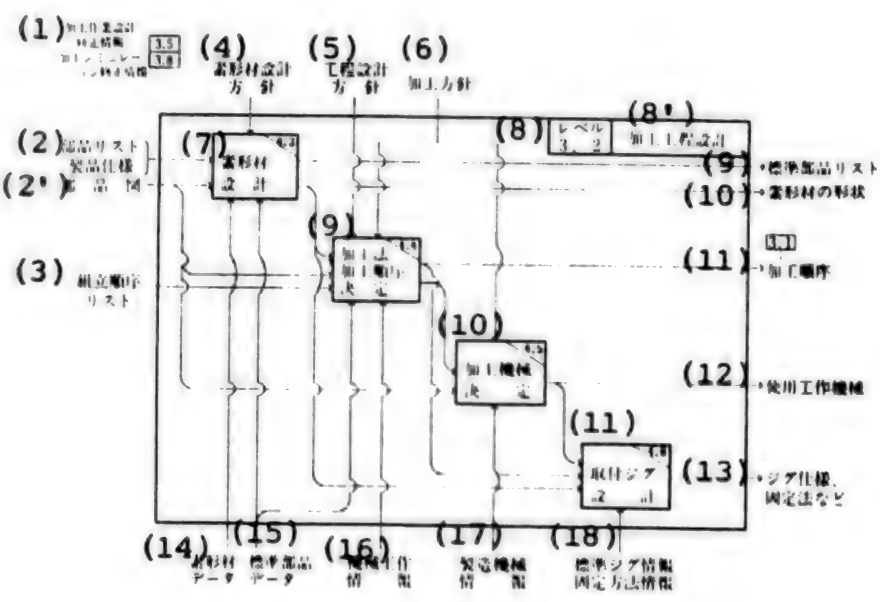
(Processing)

In this operation, the die assembly methods and assembly equipment, jigs, and tools are determined from the die assembly sequence lists, die data, parts drawings, parts assembly diagrams, parts lists, and production control data.

Correctional data are fed back, depending on the results of the processing/machining procedures, assembly jobs, and assembly simulation. Correctional data may also be fed back into level 4.1, depending on the assembly method results.

3.4.2 Processing Procedure Design (Level 3.2)

Figure 3.7 Processing/Machining Procedure Design



Key:

1. Processing/machining job design correctional data
   Processing/machining simulation correctional data
2. Parts lists, product specifications
2'. Parts drawings
3. Assembly sequence lists
4. Stock material design guidelines
5. Procedure design guidelines
6. Processing/machining guidelines
7. Stock material design
8. Level 3.2
8'. Processing/machining procedure design
9. Standard parts lists
10. Stock material shape
11. Processing/machining sequence
12. Machine tools used
13. Jig specifications, fixing methods, etc.
14. Stock material data
15. Standard parts data
16. Machine work data
17. Fabricating machine data
18. Standard jig data, fixing method data

As is diagrammed in Figure 3.7, the processing/machining procedure design operation is made up of four processing units which perform stock material design, processing/machining method and sequence determination, processing/machining machine determination, and attachment jig design.

(1) Stock Material Design (Level 4.3)

(Input)

Parts lists (used to retrieve standard parts)
Parts drawings (used for non-standard parts)
Product specifications (including hardness, surface properties)

(Output)

Standard parts lists (name of part, drawing number, material quality, tolerances, cost, etc.)
Stock material shape data (including similar products, shaping costs, etc.)

(Reference Data)

Standard Parts Data	(JIS, industry, and manufacturer data, shapes of internally specified standard parts, material quality data, etc.)
Stock Material Data	(Size and shape of commercially available stock materials (round, flat, etc.), material quality data, obtainability of data, etc.)

(Control Data)

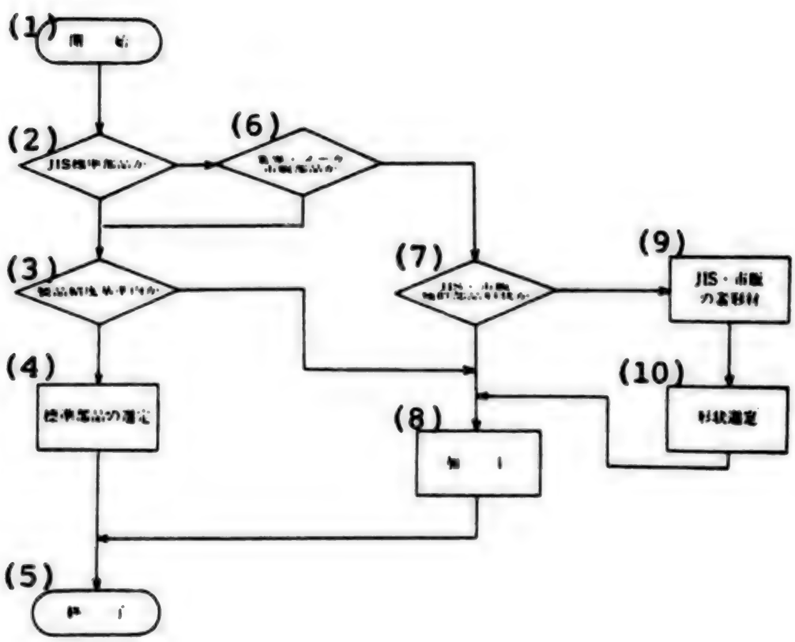
Stock Material Design Guidelines	(No control data are required for the selection of standard parts.) When retrieving similar products, selections are made so as to minimize the amount of machining required.

(Processing)

Stock material design refers to the operation of selecting stock materials for parts which cannot be fabricated by means of the supplemental machining of standard parts based on standard parts retrieval and know-how.

The data input in order to perform this stock material design are parts lists, product specifications, and parts drawings. JIS standard parts (cf Figure 3.9) are first searched for, in accordance with the parts & stock material determination flowchart given in Figure 3.8 and the parts drawings and parts lists that were input. If the item is not found among the JIS standard parts, searches are then made throughout the industry (cf Figures 3.10, 3.11) and among commercially available products from manufacturers (cf Figures 3.12, 3.13).

Figure 3.8 Parts & Stock Material Determination Flowchart



Key:

1. Start
2. JIS standard part?
3. Meets product precision criteria?
4. Standard parts selection
5. End
6. Available in industry or on commercial market?
7. Is it shaped like a similar JIS or commercially available product?
8. Processing/machining
9. JIS, commercially available stock material
10. Shape selection

Figure 3.9 Japanese Industrial Standards

Standard Number	Title of Standard	Remarks
JIS B 5004	Press-use punch-holder & die-holder	
JIS B 5006	Die-set for press use	
JIS B 5009	Round punch for press use	Types A and B
JIS B 5012	Coil spring for press use	Light-, flat-, and heavy-load types
JIS B 5013	Pole-inset die-set for press use	
JIS B 5031	Die-set precision test for press use	

Figure 3.10 Standards of Japanese Metal-Press Industrial Association

Title of Standard	Remarks
Press-punched plate parts	20 types including JIS ball-inserted die-set
Press-type die push[ers]	Used as holing dies
Press-type dowel pins	
Round punch M series	Shank tolerance M5

If the searched-for part is among these, a decision is made as to whether the degree of precision required by the product specifications is met. If it is met, then that part is selected and output. If not, an instruction to fabricate one is issued.

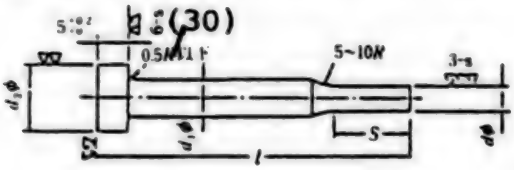
If the searched-for part is neither a JIS standard part nor a part available commercially or in the industry, then a similarly shaped part from among those available is searched for. If such a part is available, a direction to perform supplemental processing/machining is issued.

When the desired part is not found anywhere and there is no similarly shaped part available, then instructions are issued to select a suitable grade of material from among the commercially available stock materials, to make a shape selection (cf Figure 3.14), for flat plate if the part is made of

Figure 3.11 Examples of Japan Die Parts Industry Association [Standards]

(These standards are established for punch names and shapes (examples) in the Japan Die Parts Industry Association Standards)

No.	(1) 名　称	(2) 種類	(3) 形　状（例）	(4) 適　用
1	(8) 丸　パ　ン　チ	A形 C形 (5)		(19) JIS A形、C形に準じる。
2	(9) キッカー丸パンチ	C形 (6)		(20) 丸パンチにキッカーピンを装備したものでカス上り防止に使用する。
3	(10) パンチブランク	A形 C形 (5)		(21) パンチ、パイロットパンチ等の母材またはそのまま使用する。
4	(11) キッカーパンチブランク	C形 (6)		(22) パンチブランクにキッカーピンを装備したものでカス上り防止に使用する。
5	(12) パイロットパンチ	A形 C形 (5)		(23) 順送型等で直接パイロットまたは間接パイロットとして使用する。
6	(13) ストレートパイロットパンチ	C形 (6)		(24) 間接パイロットまたはピッチの狭い個所に使用する。
7	(14) バーリングパンチ			(25) タップ下穴加工用ピアスバーリングとして使用する。
8	(15) 丸　パ　ン　チ	B形 (7)		(26) 刃部直径が小さくピッチの狭い個所に使用する。
9	(16) ボールロックパンチ			(27) ボールとリテーナーによってパンチは固定される。着脱が簡単でメインテナンスに便利である。
10	(17) 標準異形パンチ	A形 C形 (5)		(28) パンチブランクまたは丸パンチを母材とし、切刃部を標準異形状で示すことができる。
11	(18) 特殊異形パンチ	A形 C形 (5)		(29) パンチブランクまたは丸パンチを母材とし、切刃部を標準異形状で示すことができない。



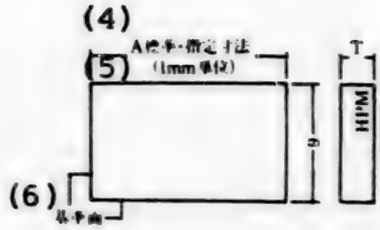
$d^{+0.01}_{0}$ (31) 最小−最大	(32) ステップ	d_1 ms	d_2 $^{0}_{-0.2}$	$S^{\pm0.2}$ 4	6	8	13	19	25	$l^{+0.4}_{-0.2}$ 40	50	60	70	80	(33) 種類の数
1.0−2.011	0.2	$4^{+0.009}_{+0.001}$	7	○	○	○				○	○	○			6×3×3=54
2.0−4.021	0.5					○	○			○	○	○			5×2×3−3=27
2.0−5.031	0.5	$5^{+0.001}_{+0.004}$	8			○	○			○	○	○	○		7×2×4=56
2.0−5.031	0.5	$6^{+0.009}_{+0.001}$	9			○	○			○	○	○	○		6×2×4=48
5.0−6.031	0.5					○	○			○	○	○	○		3×2×4−8=32
6.0−8.031	0.5	$8^{+0.012}_{+0.004}$	11				○	○			○	○	○	○	5×2×4=40
8.0−10.021	0.5	$10^{+0.012}_{+0.006}$	13				○	○			○	○	○	○	5×2×4=40
10.0−13.031	0.5	$13^{+0.015}_{+0.001}$	16				○	○			○	○	○	○	7×2×4×56
13.0−16.031	1.0	$16^{+0.013}_{+0.001}$	19					○	○		○	○	○	○	4×2×4×32
16.0−20.041	1.0	$20^{+0.016}_{+0.004}$	23					○	○		○	○	○	○	5×2×4=40
20.0−25.051	1.0	$25^{+0.015}_{+0.004}$	28					○	○		○	○	○	○	6×2×4=48

Figure 3.12 Commercially Available Finished Plate

(1) 材究－ A × B × T

(2) 標準サイズ……HMM－160×125×13：

(3) A寸法指定……HPM－165×125×16：

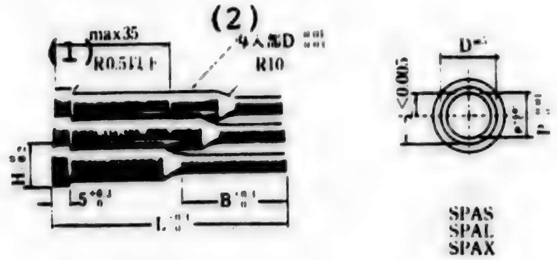


(7)

■規格・価格表（大字は標準サイズ）

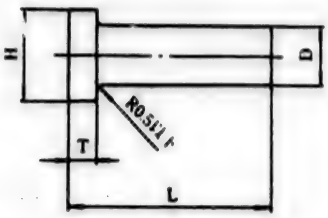
A	×	T B	8	10	13	16	20	22	25	28	34
25～100											
101～249		25									
250											
30～100											
101～200		40									
201～200											
400											
30～ 59			A×24	A×26	A×28	A×30	A×32				
60			1250	1410	1480	1540	1570				
61～100			A×21	A×24	A×25	A×26	A×28				
101～200		60	A×17	A×19	A×20	A×22	A×24				
201～300			A×17	A×19	A×20	A×22	A×24				
301～400			A×17	A×19	A×20	A×22	A×24				
401～500			A×15	A×17	A×18	A×20	A×22				
30～ 79			A×25	A×29	A×30	A×31	A×33	A×35	A×37		
80			1500	1700	1820	1890	2100	2200	2340		
81～ 99			A×21	A×24	A×25	A×26	A×29	A×30	A×33		
100			1540	1760	1950	1910	2200	2340	2400		
101～200		80	A×18	A×21	A×22	A×23	A×26	A×27	A×29		
201～300			A×18	A×21	A×22	A×23	A×26	A×27	A×29		
301～400			A×18	A×21	A×22	A×23	A×26	A×27	A×29		
401～500			A×18	A×21	A×22	A×23	A×26	A×27	A×29		
30～ 99			A×26	A×30	A×32	A×33	A×34	A×36	A×38		
100			1860	2100	2250	2260	2380	2480	2680		
101～124			A×22	A×25	A×27	A×28	A×29	A×30	A×32		
125		100	2100	2370	2400	2410	2860	2940	3170		
126～200			A×21	A×23	A×24	A×25	A×28	A×29	A×31		
201～300			A×20	A×22	A×23	A×24	A×27	A×28	A×30		
301～400			A×20	A×22	A×23	A×24	A×27	A×28	A×30		
401～500			A×20	A×22	A×23	A×24	A×27	A×28	A×30		

Figure 3.13 Examples of Standard Products Marketed by Manufacturers



(3) カタログ№ / (4) タイプ	D	(5) 全長 L	(6) 丸パンチ mih P	max	(7) 変形パンチ P. Kmax	Wmin	B	H
(8) ショートタイプ	3	40 50 60 70 80	1.00	2.97	·			5
(9) 丸 SPAS	4	40 50 60 70 80	1.00	3.97	3.90	1.00	8	7
	5	40 50 60 70 80	2.00	4.97	4.90	1.20		8
(10) 変形 SPDS	6	40 50 60 70 80	2.00	5.97	5.90	1.50		9
SPRS	8	(40) 50 60 70 80 90 100	3.00	7.97	7.90	2.00		11
SPES	10	(40) 50 60 70 80 90 100	3.00	9.97	9.90	2.50	13	13
SPGS	13	(40) 50 60 70 80 90 100	6.00	12.97	12.90	3.00		16
	16	(40) 50 60 70 80 90 100	10.00	15.97	15.90	4.00		19
	20	(40) 50 60 70 80 90 100	13.00	19.97	19.90	5.00	19	23
	25	(40) 50 60 70 80 90 100	18.00	24.97	24.90	6.00		28
	—	(11) D32 38 45の大径パンチ規格はP69を参照						
(12) ロングタイプ	3	50 60 70 80	1.00	2.97				5
(13) 丸 SPAL	4	50 60 70 80	1.00	3.97	3.90	2.00	13	7
	5	50 60 70 80	2.00	4.97	4.90	2.00		8
(14) 変形 SPDL	6	50 60 70 80	2.00	5.97	5.90	2.00		9
SPRL	8	50 60 70 80 90 100	3.00	7.97	7.90	2.50		11
SPEL	10	50 60 70 80 90 100	3.00	9.97	9.90	2.50	19	13
SPGL	13	50 60 70 80 90 100	6.00	12.97	12.90	3.00		16
	16	60 70 80 90 100	10.00	15.97	15.90	4.00		19
	20	60 70 80 90 100	13.00	19.97	19.90	5.00	25	23
	25	60 70 80 90 100	18.00	24.97	24.90	6.00		28
	S	(15) D32 38 45の大径パンチ規格はP69を参照						
(16) エキストラタイプ	3	50 60 70 80	2.00	2.97			19	5
	4	50 60 70 80	2.00	3.97				7
(17) 丸 SPAX	5	60 70 80	2.00	4.97			25	8
	6	60 70 80	2.00	5.97				9
	8	60 70 80 90 100	3.00	7.97				11
	10	60 70 80 90 100	3.00	9.97			30	13
	13	60 70 80 90 100	6.00	12.97				16
	16	70 80 90 100	10.00	15.97				19
	20	70 80 90 100	13.00	19.97			40	23
	25	70 80 90 100	18.00	24.97				28

Figure 3.14 Example of Commercially Available Blank

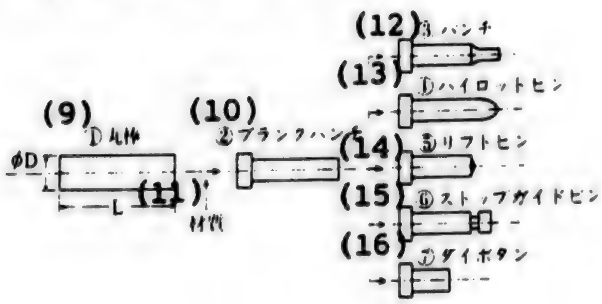


(1) 単位mm

D		H		T		L				
(2) 基準寸法	(3) 許容差(n6)	(4) 基準寸法	(5) 許容差	(6) 基準寸法	(7) 許容差					
3	+0.01 +0.004	5	0 −0.2	3	+0.3 0	40	50	60		
4	+0.016 +0.008	6								
5		7								
6		8							70	80
8	+0.019 +0.010	11		4						
10		13								
13	+0.023 +0.012	16								
16		19		5						
20	+0.028 +0.015	23								
25		28								

(8) 備考. 規定なき品質上の特性はJIS B5009. プレス型用丸パンチA形に準ずる.

Figure 3.15 Example of Parts Fabrication



Key to Figures 3.14, 3.15:

1. Units: mm
2. Standard dimensions
3. Tolerance (n6)
4. Standard dimensions
5. Tolerance
6. Standard dimensions
7. Tolerance
8. Unspecified quality-related properties shall be in accord with JIS B5009, "Press-use round-punch type A."
9. (1) Round rod
10. (2) Blank punch
11. Material quality
12. (3) Punch
13. (4) Pilot pin
14. (5) Lift pin
15. (6) Stop-guide pin
16. (7) Die button

plate, and for round or square rod material if the part is punched, and to perform the fabrication (cf Figure 3.15).

(2) Determining Processing/Machining Method, Sequence (Level 4.4)

(Input)

Parts drawings
Assembly sequence lists
Stock material shape, quality

(Output)

Processing/machining sequence
Processing/machining method, amount of machining necessary, etc.

(Reference Data)

Standard parts data	
Machine fabrication data	(precision limits for each processing/machining method, amount of machining per unit time (related to material being processed/machined))

(Control Data)

Procedure design guidelines	(delivery dates, loads, etc.)
Processing/machining guidelines	(whether to give priority to costs or precision; sequencing)

(Processing)

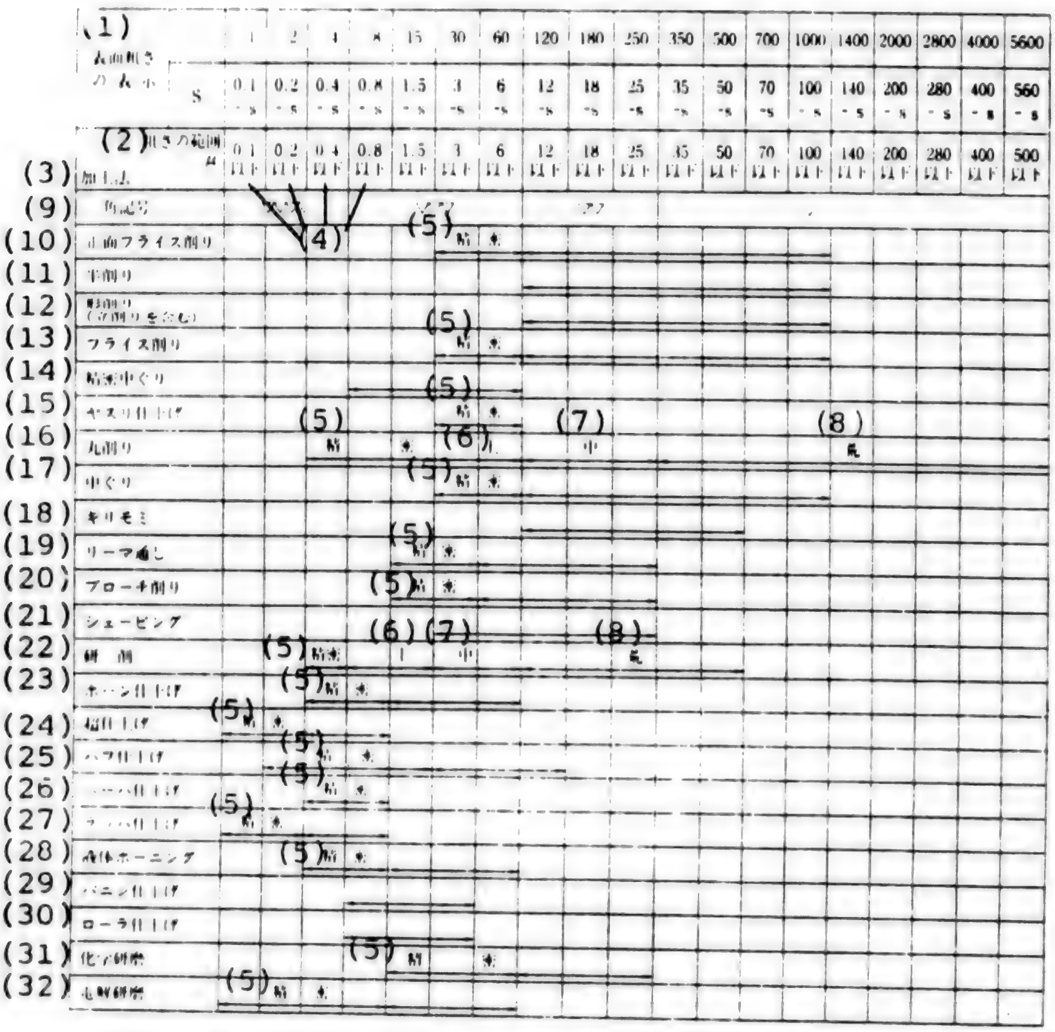
The processing/machining method and processing/machining sequence determines which processing/machining techniques are to be used, and in what sequence, according to the amount of processing/machining, quality of stock material, and precision required. Processing/machining sequencing pertains both to the processing/machining sequence for each individual part, and to the order of processing/machining priority between parts.

The data which must be input in order to determine the processing/machining method and processing/machining sequence includes the parts drawings, the assembly sequence list(s) determined at level 4.1, and the stock material shape(s) determined at level 4.3.

The processing/machining methods include such operations as machine cutting, grinding, and specialized electric and laser processing techniques. The amount of processing/machining is ascertained by comparing the shape of the stock material and the parts drawings. The processing/machining method is determined according to the shape and quality of the stock material and the degree of precision required. In Figure 3.16 is given an example of a processing/machining method determination flowchart. When fabricating a

part, rough machining or fabrication is generally performed to create the shape, and then finishing processing/machining to obtain the necessary precision. In the rough machining/fabrication, the amount of material machined away in order to create the shape is usually large. Machine cutting processes are often used for this purpose. In the finishing processing, conversely, the primary objective is to obtain precision, so the amount of material machined or processed away is small. In making die parts, heat treatments are performed following the rough fabrication process, and then the finishing processing is performed. This finishing processing often entails grinding and polishing. The relationship between processing/machining methods and roughness is represented in Table 3.1. In the manufacture of molding dies, moreover, shape classifications are made, and it is necessary to set the processing/machining method so as to correspond to the shape.

Table 3.1 Surface Roughness (Roughness Ranges for Various Processes)



Key to Table 3.1:

1. Surface roughness representation	2. Range of roughness
3. Processing/machining method	4. or less [and so across row]
5. Precision	6. High
7. Medium	8. Rough
9. Triangle symbol	10. Front milling
11. Half cutting	12. Form cutting (slotting, etc)
13. Milling	14. Precision boring
15. Filing	16. Round cutting
17. Boring	18. Drilling
19. Reaming	20. Broaching
21. Shaping	22. Grinding/polishing
23. Honing	24. Super-finishing
25. Buffing	26. Sanding
27. Lapping	28. Liquid honing
29. Panning	30. Rolling
31. Chemical polishing	32. Electrolytic polishing

In the processing/machining sequence determination, the processing/machining sequence for each part is determined (cf Figure 3.17), and the processing/machining priority for each part is determined from the assembly sequence list(s) (cf Figure 3.18). The measures employed in determining these processing/machining sequences include, for example, the method of basing the determination on the shape [of the part] (cf Figure 3.19), and the method of determining the processing/machining sequence by tracing backwards from the shape of the finished part through the changes undergone in the stock material shape, and then reversing this sequence (cf Figure 3.20[3.1]). Should any problem arise in the processing/machining sequence, feedback data are output and directed back to level 3.1. Other data may be fed back based on the results of the level-3.5 processing/machining job design and level-3.8 processing/machining simulation.

(3) Processing/Machining Machine Determination (Level 4.5)

(Input)

Parts drawings
Stock material shapes
Processing/machining data

(Output)

Machine Tools Used (Name, performance data, bed area, processable dimensions, fixed tool channels, use/nonuse and positioning of holes, etc.)

Figure 3.16 Processing/Machining Flowchart (Example)

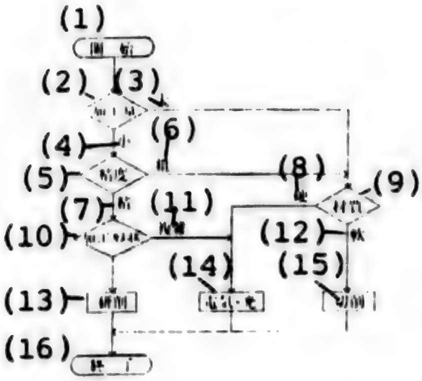


Fig 3.18 Parts Process/Machining Priority Sequencing Flowchart

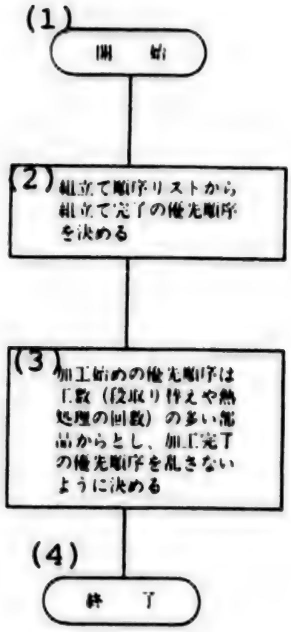


Fig 3.17 Process/Machining Sequencing Flowchart for Each Part

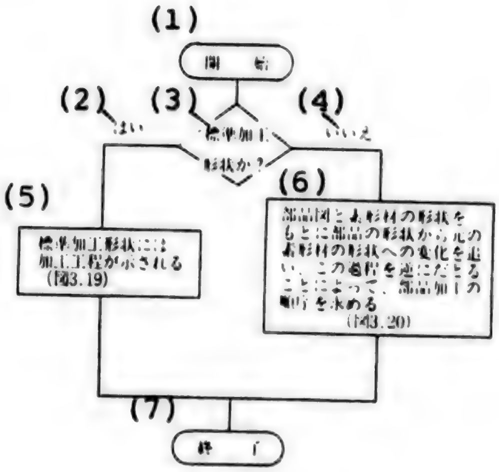
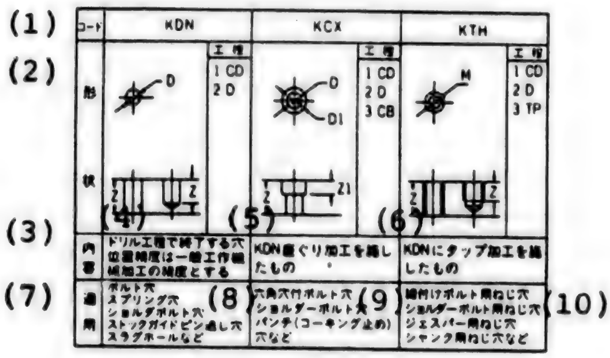


Fig 3.19 Standard Process/Machining Shapes (Examples, Japan Die Parts Industry Association)



Key to Figure 3.16:

1. Start
2. Amount machined away
3. Large
4. Small
5. Precision
6. Coarse
7. Fine
8. Hard

9. Material quality
10. Machined shape
11. Complex
12. Soft
13. Grinding/polishing
14. Electric/optical [processing]
15. Cutting
16. End

Key to Figure 3.17:

1. Start
2. Yes
3. Large
4. No
5. Processing/machining procedure(s) shown in standard processing/machining shapes (Figure 3.19)
6. Based on the part drawing and shape of stock material, changes in shape are traced backwards from finished part shape to original stock material shape. This sequence is then reversed to arrive at the proper part processing/machining sequence (Figure 3.20)
7. End

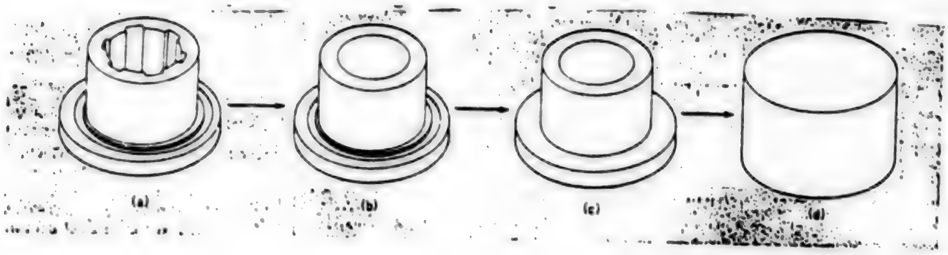
Key to Figure 3.18:

1. Start
2. Assembly completion priority sequence determined from assembly sequence list(s)
3. The initial processing/machining sequencing priority begins with those parts which require many processing steps (frequent set-up changes, heat treatments, etc.). This sequencing priority is determined so as not to disrupt the processing/machining completion priority sequencing.
4. End

Key to Figure 3.19:

1. Code
2. Shape
3. Content
4. The positioning precision for the holes finished in the drilling process is generally taken as the precision of the machine-tool process.
5. With application of KDN spot facing
6. With application of tap processing at KDN
7. Application
8. Bolt holes, spring holes, shoulder bolt holes, spoke guide pin through holes, slug holes, etc.
9. Allen bolt holes, shoulder bolt holes, punch holes (for calk stopping, etc.), etc.
10. Holes for bolt-locking screws, holes for shoulder-bolt screws, holes for Gespar screws, holes for shank screws, etc.

Figure 3.20 The changes in shape are traced back from the finished product to the original stock material, then this order is reversed to arrive at the proper processing/machining sequence.



(Reference Data)

Fabrication Machine Data (Relationship between precision and amount of material machined per unit time for each machine; processing precision limitations; bed area, shape, chuck diameter, etc.; operating costs)

(Control Data)

Processing/Machining Guidelines (Precision, loads, costs, holding equipment, etc.)

(Processing)

Fabrication (i.e. processing/machining) machine determination involves the extraction of the shape to be machined or fabricated, and the determination of the proper fabrication machine based on the amount of machining to be done and processing/machining precision specified.

The input data for performing this determination consist of parts drawings and processing/machining methods. As was noted in the section on processing/machining methods, the processing/machining operation entails rough machining and finishing machining/processing. In the rough machining stage, the shape and amount of machining done are emphasized in determining which fabrication machine to use, whereas in the finishing processing/machining, the emphasis is on the precision demanded and the qualities (primarily hardness) of the material being worked on.

Die processing/machining methods are classified into cutting processes, grinding, processes, electrical processes, laser processes, and other processes (cf Table 3.2).

In Figure 3.21 is given a flowchart for process machine determination.

Fig 3.21 Machine Determination Flowchart (Example)

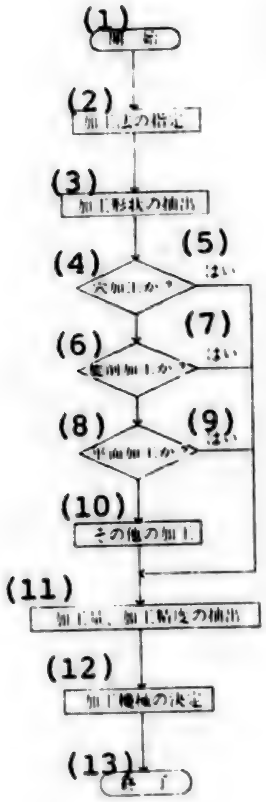
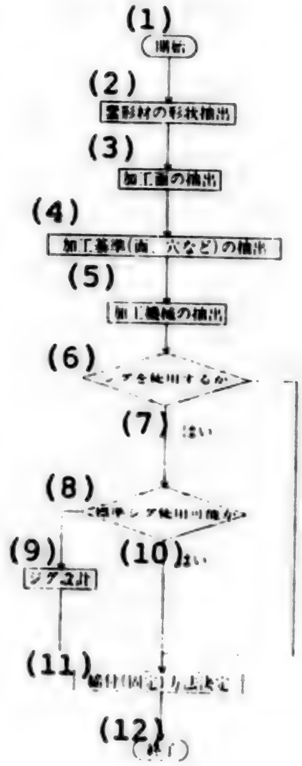


Fig 3.23 Attachment Jig Design Flowchart (Example)



Key to Figure 3.21:

1. Start
2. Processing/machining method designation
3. Extraction of processed shape
4. Hole boring operation?
5. Yes
6. Lathe turning operation?
7. Yes
8. Planing operation?
9. Yes
10. Other processing/machining
11. Extraction of machining amount, machining precision
12. Machine determination
13. End

Key to Figure 3.23:

1. Start
2. Extraction of stock material shape
3. Extraction of processing plane
4. Extraction of processing/machining standards (surfaces, holes, etc.)
5. Extraction of machine
6. Will a jig be used?

7. Yes
8. Can a standard jig be used?
9. Jig design
10. Yes
11. Determination of fastening (fixing) method
12. End

The processed shape is extracted from the parts drawings, and a determination is made as to whether the process to use should be hole boring, lathe turning, planing, or other shaping process. The processing/machining amount and processing/machining precision (hole diameter, hole interval, outer diameter, flatness, etc.) are then extracted, and the optimal processing machine (cf Table 3.2) is determined based on the processing/machining method determined at level 4.4.

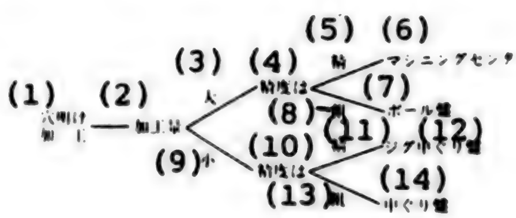
Let us look more closely at hole boring processing as an example.

Assuming that cutting processing has been specified as the processing/machining method, we find from Table 3.2 that the cutting machines which can be used for hole boring include drill presses, boring machines, and machining centers.

In die holing processes, one usually does a number of machining operations on a single plate. For that reason, the hole positioning precision is an important factor, as is the machining precision for each hole (i.e. hole diameter, circularity, surface roughness, etc.) in deciding on which machine to use. Thus the most suitable machine is selected after considering the relationship between the overall precision and the relative amount of machining which must be done.

This relationship is diagrammed in Figure 3.22.

Figure 3.22 Processing Machine Determination--An Example



Key:

1. Hole boring
2. Amount of machining
3. Large
4. Precision is
5. Fine
6. Machining center
7. Drill press
8. Coarse
9. Small
10. Precision is
11. Fine
12. Jig boring machine
13. Coarse
14. Boring machine

(4) Fastening Jig Design (Level 4.6)

(Input)

Specifications of machine tools to use
Stock material properties, shape
Process plane, process reference plane

(Output)

Fixing method
Jig specifications

(Reference Data)

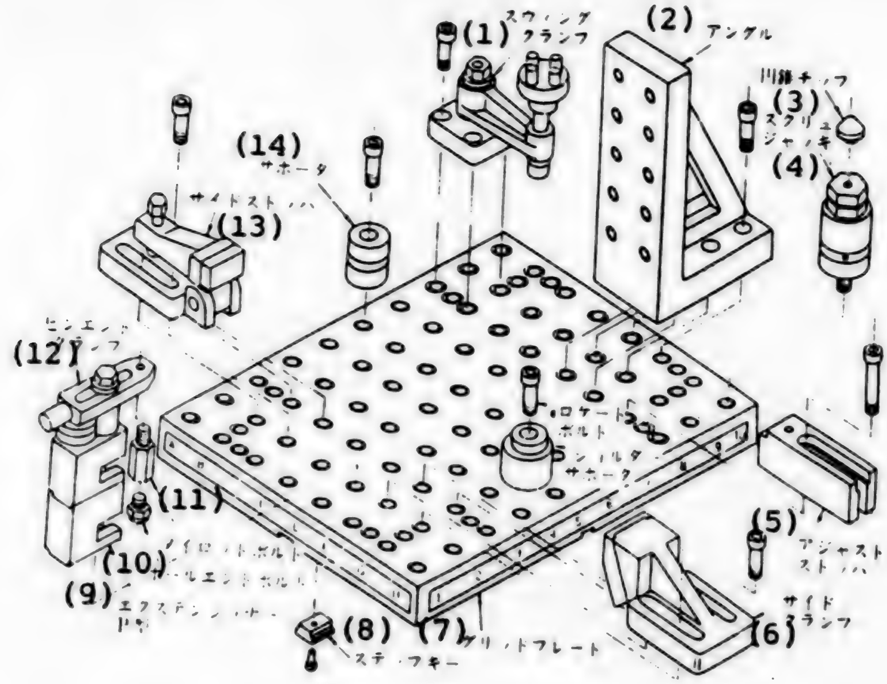
Standard jig data (jig dimensions, shape, material-quality, etc)
Fixing method data (relationship between stock material shape and method used; whether can be magnet-checked, etc)

(Processing)

Attachment jig design entails the determination of the optimal fixing method from the stock material shape and machine tool specifications, the retrieval of the necessary jigs, and the determination of the attachment positions.

The data input in order to do this attachment jig designing includes the stock material shape, method of processing any processed surfaces, processing/machining sequence, and [determining] the processing reference plane and processing machines. Following the attachment jig design flowchart given in Figure 3.23, the stock material shape, processing surface, and processing standards (surfaces, holes, etc.) are extracted, and optimal determinations are made for which positioning method to use, which mechanism fastening method to use, and at which position to fasten the stock material. The positioning is determined, firstly, on the basis of whether or not a jig will be used, the shape of the stock material, the processing/machining conditions, the precision required, and the processing machine specifications. Next the question of whether or not a standard jig can be used is decided. The reference data pertains to such items as universal dividing heads, vices, and electromagnetic checking, internally standardized jig lists by similar processed/machined item, and commercially available jig units (cf Figure 3.24). When standard jigs will not suffice, one proceeds to the new jig design process. Finally the fastening method is determined, making decisions on whether to use screws (bolts) or some other method, what shape to make the fasteners (cf Figure 3.25), whether to consider the hardness of the processed item in selecting the fastening locations, and what attachment method will make for the easiest attachment and detachment.

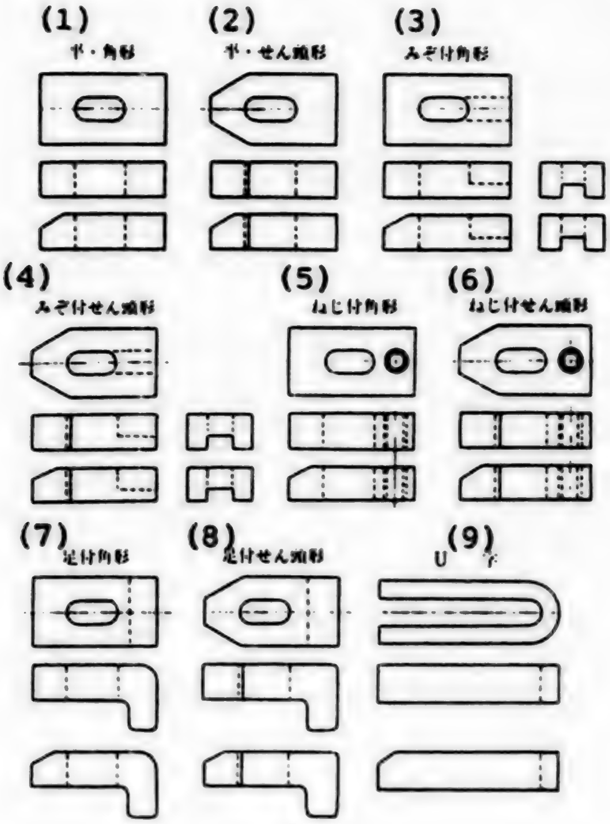
Figure 3.24 Commercially Available Jig Units
(Example of parts configuration in a block jig system)



Key:

1. Swing clamp
2. Angle
3. Conical chip
4. Screw jack
5. Adjustment stopper
6. Side clamp
7. Grid plate
8. Step key
9. P-type extensioner
10. Hole end bolt
11. Tie-rod bolt
12. Pin end clamp
13. Side stopper
14. Supporter

Figure 3.25   Fastener Shape Examples



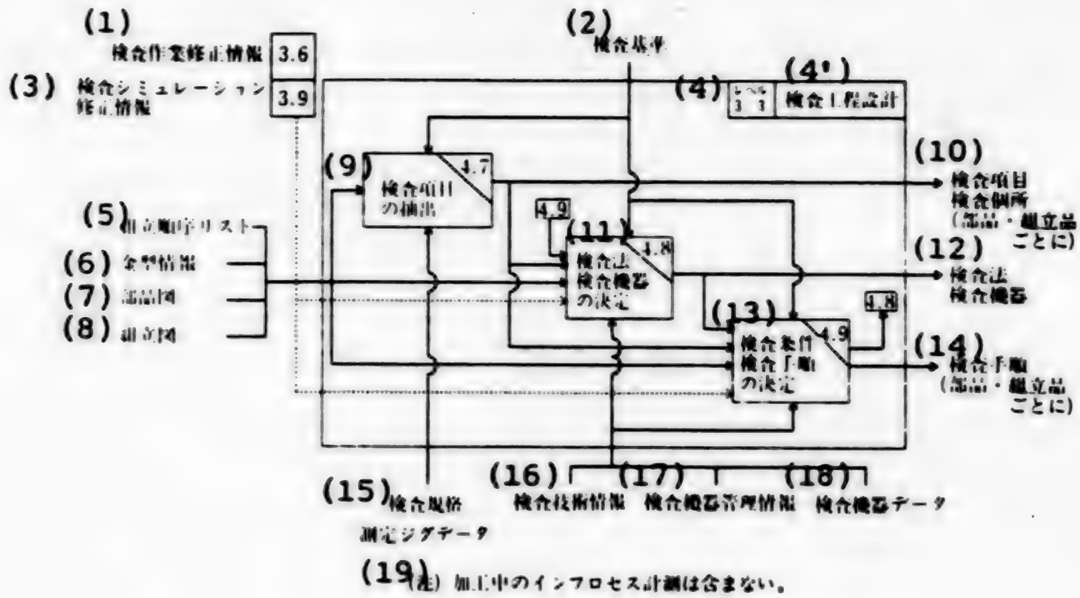
Key:

1. Flat, angle shape
2. Flat, peaked shape
3. Channeled angle shape
4. Channeled peaked shape
5. Threaded angle shape
6. Threaded peaked shape
7. Footed angle shape
8. Footed peaked shape
9. U shape

3.4.3 Inspection Procedure Design (Level 3.3)

Inspection procedure design, as is shown in Figure 3.26, is made up of three processing units, namely the extraction of inspection categories, the determination of inspection methods and inspection instruments, and the determination of inspection conditions and inspection categories [sic].

Figure 3.26 Inspection Procedure Design (Level 3.3)



Key:

1. Inspection job correctional data   2. Inspection criteria
3. Inspection simulation correctional data
4. Level 3.3   4'. Inspection procedure design
5. Assembly sequence lists   6. Die data
7. Parts drawings   8. Assembly diagrams
9. Extraction of inspection categories
10. Inspection categories, inspection locations (for each part, assembly)
11. Determination of inspection methods, inspection instruments
12. Inspection methods, inspection instruments
13. Determination of inspection conditions, inspection sequences
14. Inspection sequences (for each part, assembly)
15. Inspection standards, measurement jig data
16. Inspection technology data
17. Inspection instrument control data
18. Inspection instrument data
19. Note: Does not include in-process measurements.

(1) Inspection Category Extraction (Level 4.7)

(Input)

Assembly sequence lists
Die data
Parts drawings
Assembly diagrams

(Output)

Parts inspection categories and inspection locations
Assembly inspection categories and inspection locations

(Reference Data)

Inspection standards
Measurement jig data

(Control data)

Inspection criteria (inspection category determination criteria, etc)

(Processing)

What is here discussed as the extraction of inspection categories entails the determination of inspection categories based on measurement tolerances, shape tolerances, and surface roughness, etc., and the extraction of inspection locations. Two cases arise with respect to inspection, namely those in which inspections can be made on a part-by-part basis, and those in which inspections can only be made of the [entire] assembly. Hence both the assembly and its constituent parts are subject to inspection.

The data input for the purpose of extracting these inspection categories include assembly sequence lists, die data, parts drawings, and assembly diagrams. The extraction of each location to be inspected, moreover, is done concurrently with the determination of the inspection categories, based on the inspection criteria (such as the criteria for determining inspection categories, etc.). Dimensions, positional precision, and shape precision (perpendicularity, parallelism, and other related-shape categories) are considered in assembly inspection. Dimensions, positional precision, shape precision (including both single and related-shape categories), surface roughness, and surface luster are considered in parts inspection. Position and shape precision are defined in "Definition and Expression of Geometric Deviation" (JIS B-0621) (cf Table 3.3).

Table 3.3 Types of Geometric Deviation

Type		Form Applied To
Shape Deviation	Perpendicularity Flatness Roundness Cylindricalness	Single forms
	Linear contour Planar contour	Single forms or linked forms
Attitude Deviation	Parallelism Perpendicularity Gradient (Slant)	Linked (related) forms
Positional Deviation	Positionality Coaxilarity, Concentricity Symmetry	
Deflection	Circular deflection Total deflection	

In general, three-dimensional measuring equipment, as may be understood from Figures 3.27 and 3.28, has functions for measuring dimensions, positions, basic shapes, and contours. When extracting inspection categories as inspection criteria, therefore, it is necessary to perform extractions that suit these programs.

(2) Determination of Inspection Methods, Inspection Instruments (Level 4.8)

(Input)

- Assembly sequence lists
- Die data
- Parts drawings
- Assembly diagrams
- Parts inspection categories, inspection locations
- Assembly inspection categories, inspection locations

(Output)

- Inspection methods (Separately for engineering, electrical, mechanical methods and according to whether contact or non-contact method)
- Inspection instruments (3D measurers, contour shape measurers, circularity measurers, etc)

(Reference Data)

Inspection technology data
Inspection instrument control data
Inspection instrument data

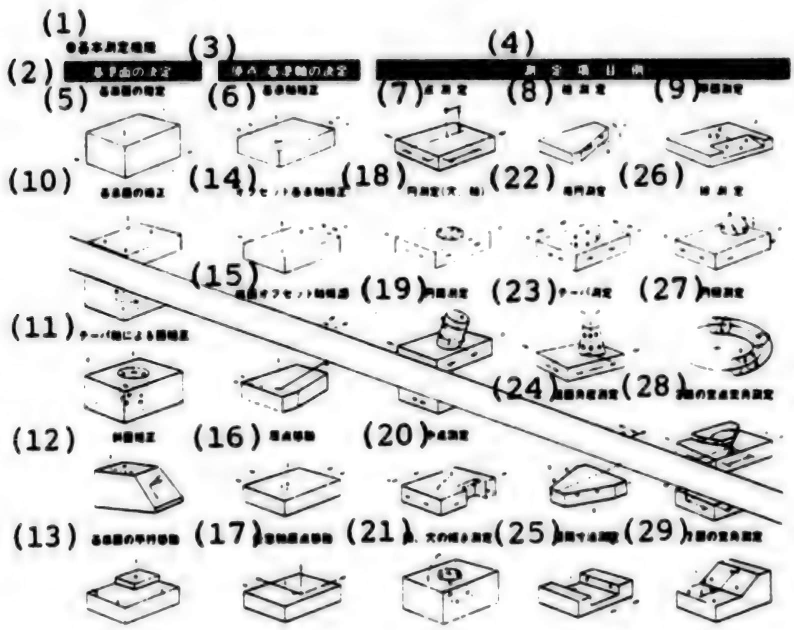
(Control Data)

Inspection criteria (such as order of priority in selecting inspection methods)

(Processing)

What is here discussed as inspection method determination entails the determination of methods and modes from among such method classifications as optical, electrical, and mechanical, and such mode classifications as contact and non-contact.

Figure 3.27 Program Menu for 3D Measurer Data Processing
(From catalog of Mitsutoyo KK)



Key:

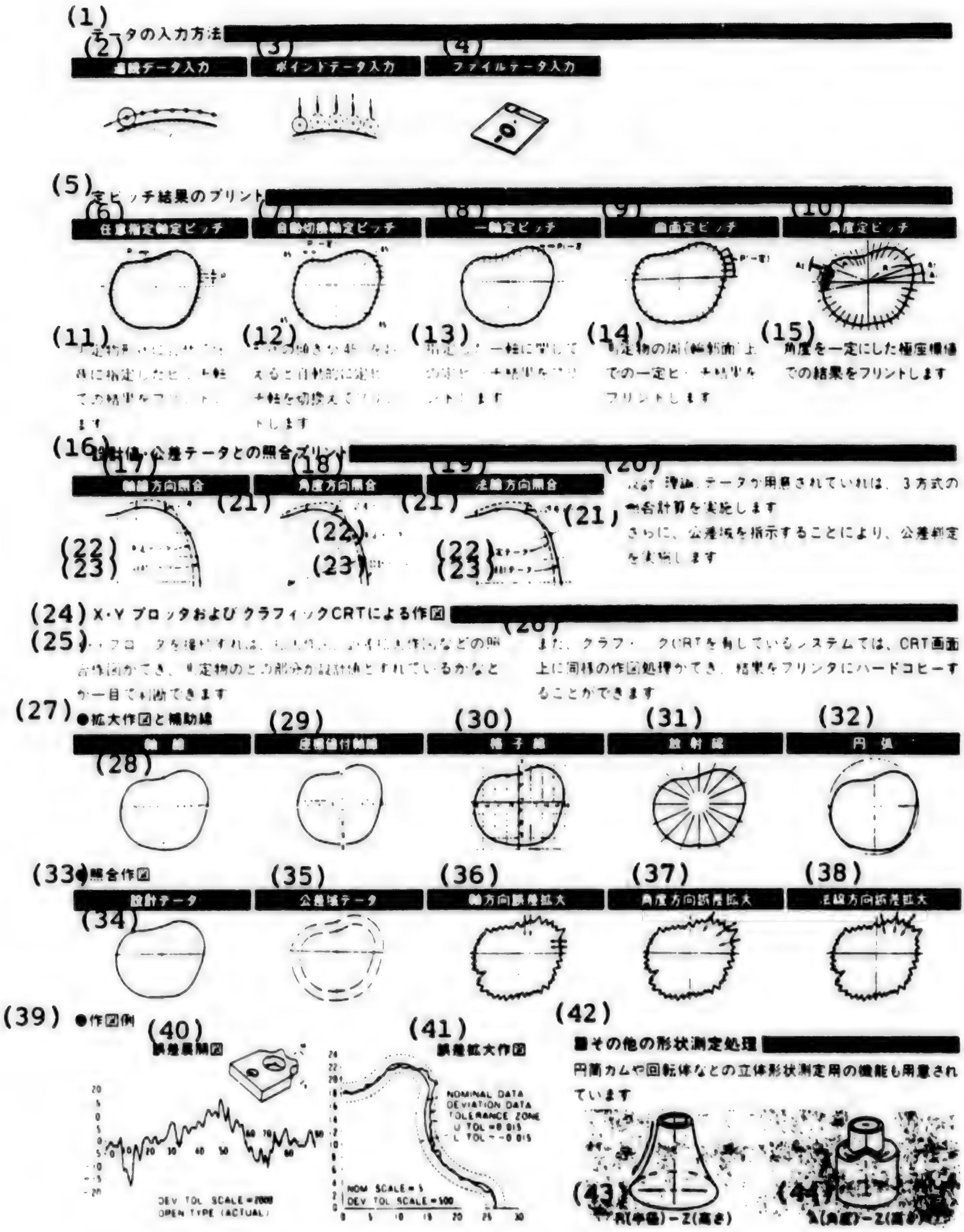
1. Basic measurement functions
2. Reference plane determination
3. Origin, reference axis determination
4. Examples of measurement categories
5. Reference plane measurement
6. Reference axis correction
7. Point measurement

8. Linear measurement
9. Planar measurement
10. Reference plane correction
11. Planar correction by tapered axis
12. Gradient correction
13. Parallel shift of reference plane
14. Offset reference axis correction
15. End-surface offset axis correction
16. Origin shift
17. Shift of any axis [or] point
18. Circle measurement (hole, axle)
19. Cylinder measurement
20. Mid-point measurement
21. Measurement of axial or hole inclination
22. Ellipse measurement
23. Taper measurement
24. Measurement of [illegible] surface angle
25. Measurement of interplanar dimensions
26. Sphere measurements
27. Torus measurement
28. Measurement of angle of intersection of two lines
29. Measurement of angle of intersection of two planes

Key to Figure 3.28:

1. Data input method
2. Continuous data input
3. Point data input
4. File data input
5. Fixed-pitch results printing
6. Any designated axis fixed pitch
7. Auto-switched axis fixed pitch
8. Single-axis fixed pitch
9. Curved surface fixed pitch
10. Angle fixed pitch
11. Prints results with axis of any designated pitch in conjunction with shape of measured object
12. Automatically switches the fixed-pitch axis when the inclination of the shape exceeds 45° and prints
13. Prints fixed-pitch results relative to designated single axis
14. Prints results of single fixed pitch on periphery (contour surface) of measured object
15. Prints results at polar coordinates for a constant angle
16. Printing with reference to design values and tolerance data
17. Axis line direction reference
18. Angle direction reference
19. Normal line direction reference
20. If design (theoretical) data have been prepared, three types of reference computations are implemented.
    By designating the tolerance zone, moreover, tolerance judgments are implemented.
21. Tolerance data
22. Measurement data
23. Design data
24. Drafting by means of X•Y plotters and graphics-capable CRT's
25. If an X•Y plotter is connected, it is possible to make reference drawings such as enlarged drawings and error-enlarged drawings, so that one can tell at a glance what part of the measured object does not agree with the design values.
26. With systems in which a graphics-capable CRT is used, the same drafting processes can be done on the CRT screen, and hard copies of the results printed out on a printer.

Figure 3.28 Program Menu for 3D Measurer Data Processing
(from catalog of Mitsutoyo KK)



27. Enlarged drawings and auxiliary lines
28. Axis lines
29. Axis lines with coordinate values
30. Lattice lines
31. Radial lines
32. Circular arcs
33. Reference drawings
34. Design data
35. Tolerance zone data
36. Axial direction error enlargement
37. Angular direction error enlargement
38. Normal line direction error enlargement
39. Drafting examples
40. Error expansion chart
41. Error enlargement drafting
42. Other shape measurement processing
    Functions are also available for measuring such solid shapes as cylindrical cams and rotated bodies.
43. R (radius) - Z (height)
44. A (angle) - Z (height)

Inspection instruments include both general-purpose and special-purpose instruments. General-purpose instruments include contour shape measurers, circularity measurers, length measurers, and surface roughness measurers, etc. In using such instruments, the following three cases are possible. (1) General-purpose instruments only are used. (2) Special-purpose instruments only are used. (3) Both general-purpose and special-purpose instruments are used. The third of these cases, namely the use of both general- and special-purpose instruments, is the most practical.

The input data used in determining the inspection methods include assembly sequence lists, die data, parts drawings, assembly diagrams, and the data determined at level 4.7 on inspection categories and locations. The appropriate inspection methods are then determined, according to such factors as precision, efficiency, cost, and inspection criteria (inspection method order of priority, etc.).

The determination of the inspection instruments is done in accordance with such input data as parts and assembly inspection categories and inspection locations, and on the inspection method(s) determined in the current process. Depending on the results of the level-3.9 inspection simulation and the level-4.9 inspection conditions and inspection sequence, correctional data may also be fed back.

(3) Determination of Inspection Conditions, Inspection Sequence (Level 4.9)

(Input)

Assembly sequence lists
Die data
Assembly diagrams, parts drawings
Inspection categories, inspection location data
Inspection methods, inspection instrument data

(Output)

Inspection conditions, inspection sequence

(Reference Data)

Inspection technology data
Inspection instrument control data
Inspection instrument data

(Control Data)

Inspection criteria

(Processing)

What is here discussed as inspection conditions refers to such set conditions as measurement levels for each measurement location, measurement criteria positioning, and method of attaching products being inspected. The inspection sequence is the order in which the inspection instruments decided on are used.

The data input for determining these inspection conditions and inspection sequence include assembly sequence lists, die data, assembly diagrams, parts drawings, the inspection categories and locations determined at level 4.7, and the inspection instruments output at level 4.8. Correctional data may also be fed back depending on the results of the inspection job and inspection simulation.

It is here that the inspection conditions and inspection sequence are determined for parts and assemblies, respectively.

In the process of determining the inspection conditions, the inspection item attachment surfaces, measurement standard positioning, and measurement precision levels are determined, based on inspection location and inspection instrument data.

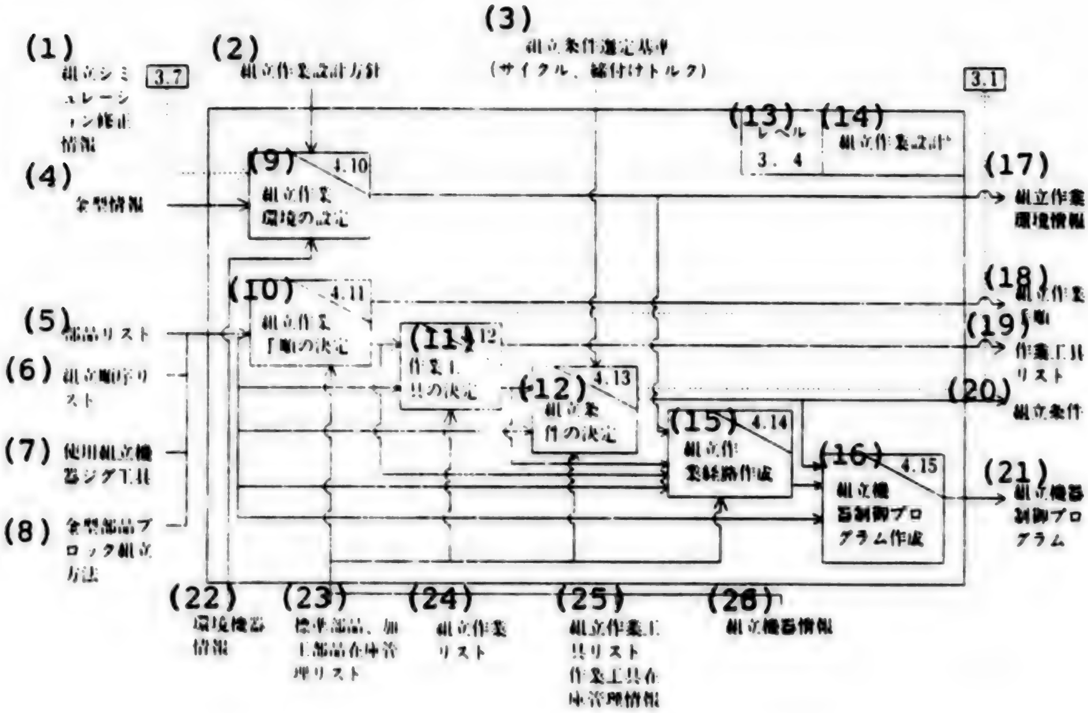
In the process of determining the inspection order, the inspection sequence is determined according to the measurement standard position, inspection location, inspection category, and measurement precision level, taking into consideration the attachment surface. Some possible evaluation functions when determining the inspection sequence are, for example, the number of setup steps and time required every time the inspection instrument(s) must be changed. The sequence which minimizes these evaluation functions is output. These evaluation functions need to be defined inside the inspection criteria which is part of the control data.

The reference data include inspection technology data, inspection instrument control data, and inspection instrument data.

3.5 Job Design (Level 2.2) Detailing

3.5.1 Assembly Job Design (Level 3.4)

Figure 3.29 Assembly Job Design (Level 3.4)



Key:

1. Assembly simulation correctional data
2. Assembly job design guidelines
3. Assembly condition selection criteria (cycle, tightening torque)
4. Die data 5. Parts lists
6. Assembly order lists
7. Assembly equipment jigs and tools used
8. Die parts block assembly methods
9. Determination of assembly job environment
10. Determination of assembly job sequences
11. Determination of job tools
12. Determination of assembly conditions
13. Level 3.4 14. Assembly job design
15. Assembly job routing
16. Assembly equipment control programming
17. Assembly job environment data
18. Assembly job sequences 19. Job tool lists
20. Assembly conditions

21. Assembly equipment control programs
22. Environmental equipment data
23. Standard parts lists, inventory control lists for processed/machined parts
24. Assembly job lists
25. Assembly job tool lists, assembly tool inventory control data
26. Assembly equipment data

In the assembly job design, a basic consideration is mating the work with FMS, as diagrammed in Figure 3.29. This operation is made up of seven [sic] processing units, namely assembly job environment determination, assembly job sequence determination, job tool determination, assembly conditions determination, assembly job routing, and assembly equipment control programming.

(1) Assembly Job Environment Determination (Level 4.10)

(Input)

Die data

(Output)

Assembly job environment data

(Reference Data)

Environment equipment data

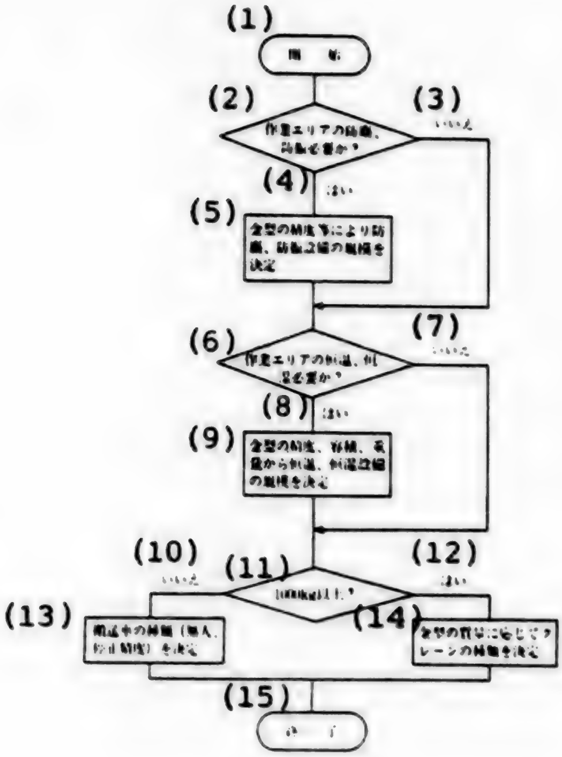
(Control Data)

Assembly job design guidelines

(Processing)

The data input in this operation are such die information as die precision, functions, and weights. Based on the assembly job design guidelines and referencing the environmental equipment data, a work environment suitable to the die assembly (setting maximum levels for dust, noise, and vibration, and allowable ranges for temperature and humidity) and methods for moving the mechanism parts in and out (unmanned carrier vehicles, hoists, etc.) are determined. Depending on the results of the assembly simulation, correctional data may also be fed back. The course of this process is diagrammed in a flowchart in Figure 3.30.

Figure 3.30 Assembly Job Environment Determination



Key:

1. Start
2. Are dust and vibration prevention measures needed in work area?
3. No 4. Yes
5. Determination of scale of dust and vibration control equipment according to die precision, etc.
6. Must temperature and humidity be kept constant in work area?
7. No 8. Yes
9. Determination of scale of temperature and humidity control equipment according to die precision, dimensions, and weight
10. No 11. 1000 kg or more?
12. Yes
13. Determination of type of carrier vehicle (unmanned, stopping precision)
14. Determination of crane type according to die mass
15. End

(2) Assembly Job Sequence Determination (Level 4.11)

(Input)

Parts lists
Assembly sequence lists
Die parts assembly methods
Die parts block assembly methods
Assembly equipment, jigs

(Output)

Assembly job sequences

(Reference Data)

Assembly job lists (press fitting, insertion, screw tightening, etc.)

(Processing)

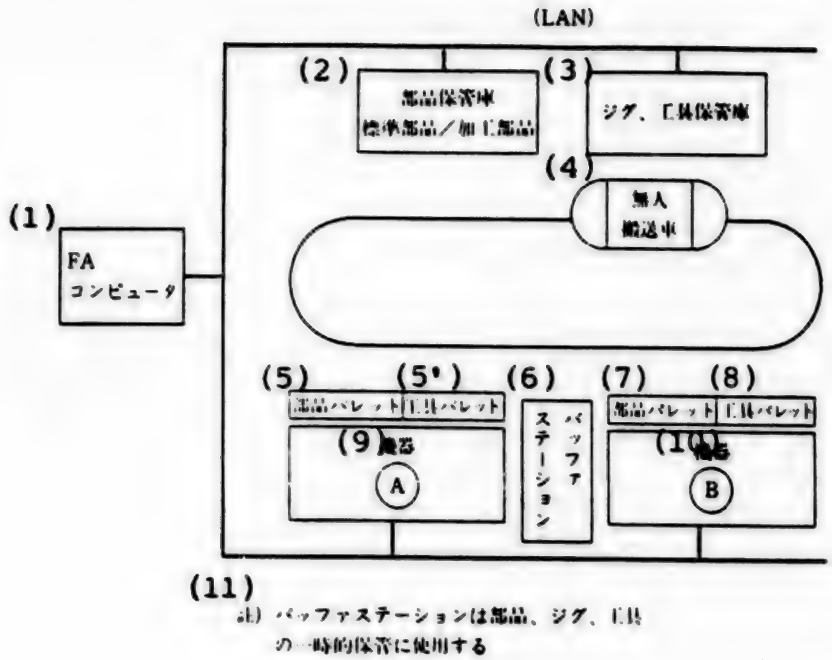
Assembly job sequencing involves determining the detailed sequences to be followed in the assembly job, based on such data as the assembly order, assembly method, and assembly equipment and jigs used.

The component parts for the dies are stored in automatic warehouses (i.e. holding areas for parts, jigs, and tools) or at buffer stations. These parts are conveyed to the assembly stage via unmanned carrier vehicles or the like and assembled by robots or other means. The equipment is tied together with LAN interconnections and controlled with an FA computer.

As a rule, work in progress is not returned to the shelf, but is kept at buffer stations (temporary holding platforms). These locations and conditions are recorded in the FA computer as control data. Of the component parts, plate material is as a rule assembled [sic] and transported while loaded on pallets. In Figure 3.31 is given an example of an assembly job block layout. Figure 3.32 is a flowchart for the assembly job design operation. Depending on the results of the level-3.7 assembly simulation, correctional data are also fed back.

The data input in this process include parts lists, assembly sequence lists, die parts assembly methods, and assembly equipment and jigs. The assembly job sequences are determined while referring to assembly job lists. The process flow is diagrammed in Figure 3.33. Should any difficulties arise in the determination of the assembly job sequences, assembly procedure design correctional data is fed back. Depending on the results of the level-3.7 assembly simulation, moreover, correctional data may be fed back.

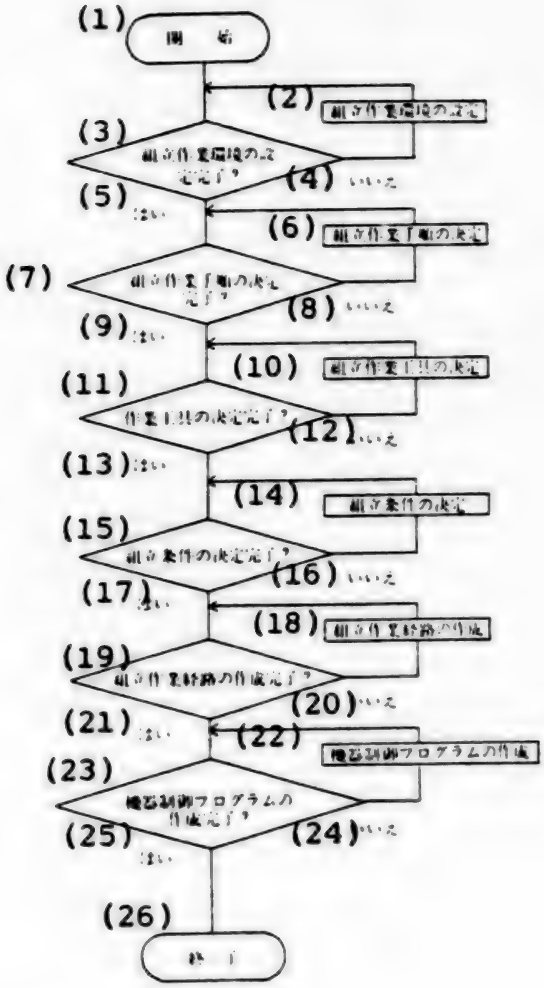
Figure 3.31   Assembly Job Block Layout Example



Key:

1. FA computer
2. Parts holding area (standard parts / fabricated parts)
3. Inventory control area for jigs and tools
4. Unmanned carrier vehicle
5. Parts pallet(s)
5'. Tools pallet(s)
6. Buffer station
7. Parts pallet(s)
8. Tools pallet(s)
9. Equipment (A)
10. Equipment (B)
11. Note: Buffer station used for temporary storage of parts, jigs, tools

Figure 3.32   Assembly Job Design Flow



Key:

1. Start
2. Assembly job environment setting
3. Is assembly job environment setting fi[illegible]d?
4. No   5. Yes
6. Assembly job sequence determination
7. Is assembly job sequence determination finished?
8. No   9. Yes
10. Assembly job tool determination
11. Is job tool determination finished?
12. No   13. Yes
14. Assembly conditions determination
15. Is assembly conditions determination finished?
16. No   17. Yes

18. Assembly job routing
19. Is assembly job routing finished?
20. No 21. Yes
22. Equipment control programming
23. Is equipment control programming finished?
24. No
25. Yes
26. End

Key to Figure 3.33:

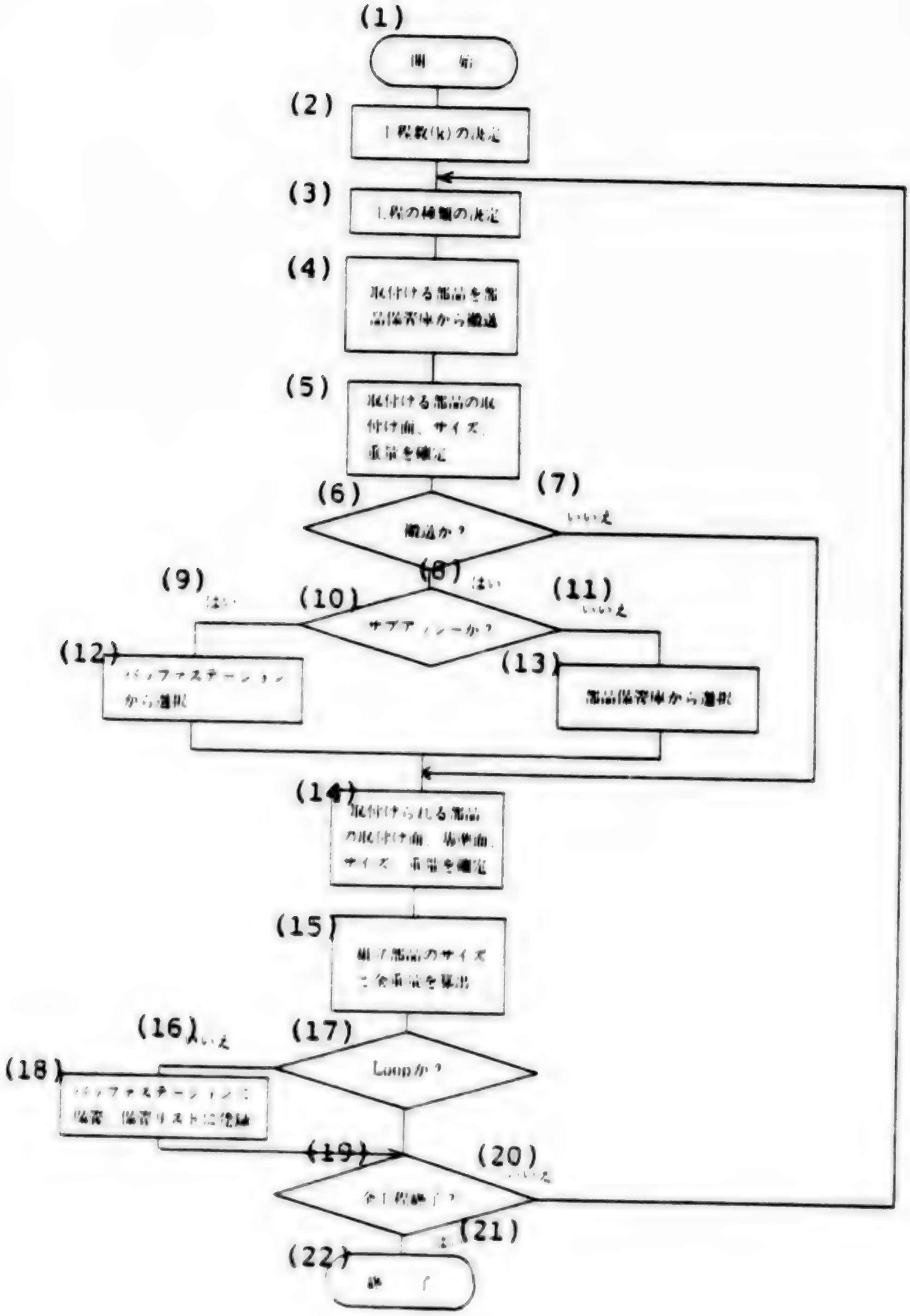
1. Start
2. Determination of number of procedures (k)
3. Procedure type determination
4. Transportation of parts to be attached from parts holding area(s)
5. Verification of attachment surfaces, sizes, and weights of parts to be attached
6. Was material transported? 7. No
8. Yes 9. Yes
10. Subassembly? 11. No
12. Select from buffer station 13. Select from parts holding area
14. Verification of attachment surfaces, sizes, and weights of parts to be attached
15. Calculation of sizes and total weight of assembly parts
16. No 17. Loop?
18. Store at buffer station, record in control list
19. Have all procedures been completed?
20. No 21. Yes
22. End

(3) Job Tool Determination (Level 4.12)

(Input)

Parts lists
Assembly sequence lists
Assembly equipment, jigs
Parts block assembly methods
Assembly job sequences

Figure 3.33   Assembly Job Sequence Determination



(Output)

Job tools lists

(Reference Data)

Assembly job tool lists
Inventory control data (inventory shelf number, attachment conditions, etc.) for assembly job tools
Assembly equipment data (assembly robots, diesets, fitting presses, etc.)

(Processing)

Job tool determination involves the determination of such things as the assembly robot hands, based on the size and weight of the assembly parts, the content of the assembly job, and the effort and precision required.

The data input for this operation include parts lists, assembly sequence lists, assembly equipment and jig lists, assembly methods, and assembly job sequences. Robot hands are selected, based on the assembly method, assembly job, and parts size and weight, while referencing the assembly job tools lists, assembly job tools inventory control data, and assembly equipment data. The assembly equipment and hand storage locations are also listed, and, when necessary, the sequence of assembly tool attachment is determined.

In Figure 3.34 is given an example of the processing flow for job tool determination. In Figure 3.35 is given an example of job tool changing sequence processing flow. Should irregularities arise in the determination of job tools, correctional data are fed back to the assembly procedure design operation. Other correctional data may be fed back, moreover, depending on the outcome of the level-3.7 assembly simulation.

Key to Figure 3.34:

1. Start
2. Selection of assembly equipment (robots)
3. Determination of tools and jigs used
4. Determination of robot hand type
5. Tool change
6. No
7. Yes
8. Tool change sequencing
9. No
10. Are all procedures finished?
11. Yes
12. Equipment, tool listing
13. End

Figure 3.34 Job Tool Determination

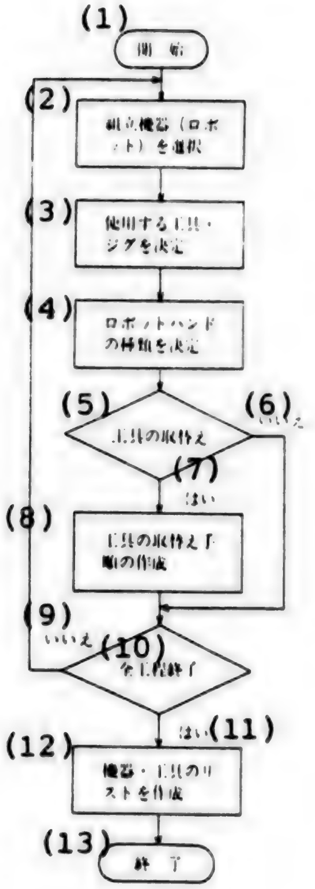
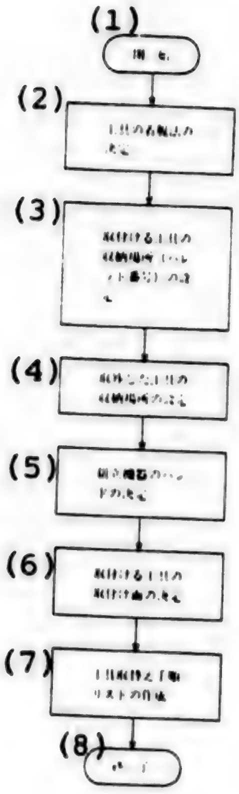


Figure 3.35 Job Took Changing Sequence Determination



Key to Figure 3.35:

1. Start
2. Determination of method of attaching, detaching tools
3. Determination of holding location (pallet number) for tools attached
4. Determination of holding location for tools detached
5. Determination of assembly equipment hands
6. Determination of attachment surface for tools attached
7. Listing of tool changing sequences
8. End

(4) Assembly Conditions Determination (Level 4.13)

(Input)

Parts lists
Assembly sequence lists
Assembly equipment, jigs, tools
Assembly job sequences
Job tools

(Output)

Assembly conditions

(Reference Data)

Assembly equipment data

(Control Data)

Assembly condition selection criteria (fitting standards, pressure levels, screw tightening torques, pressure cycles)

(Processing)

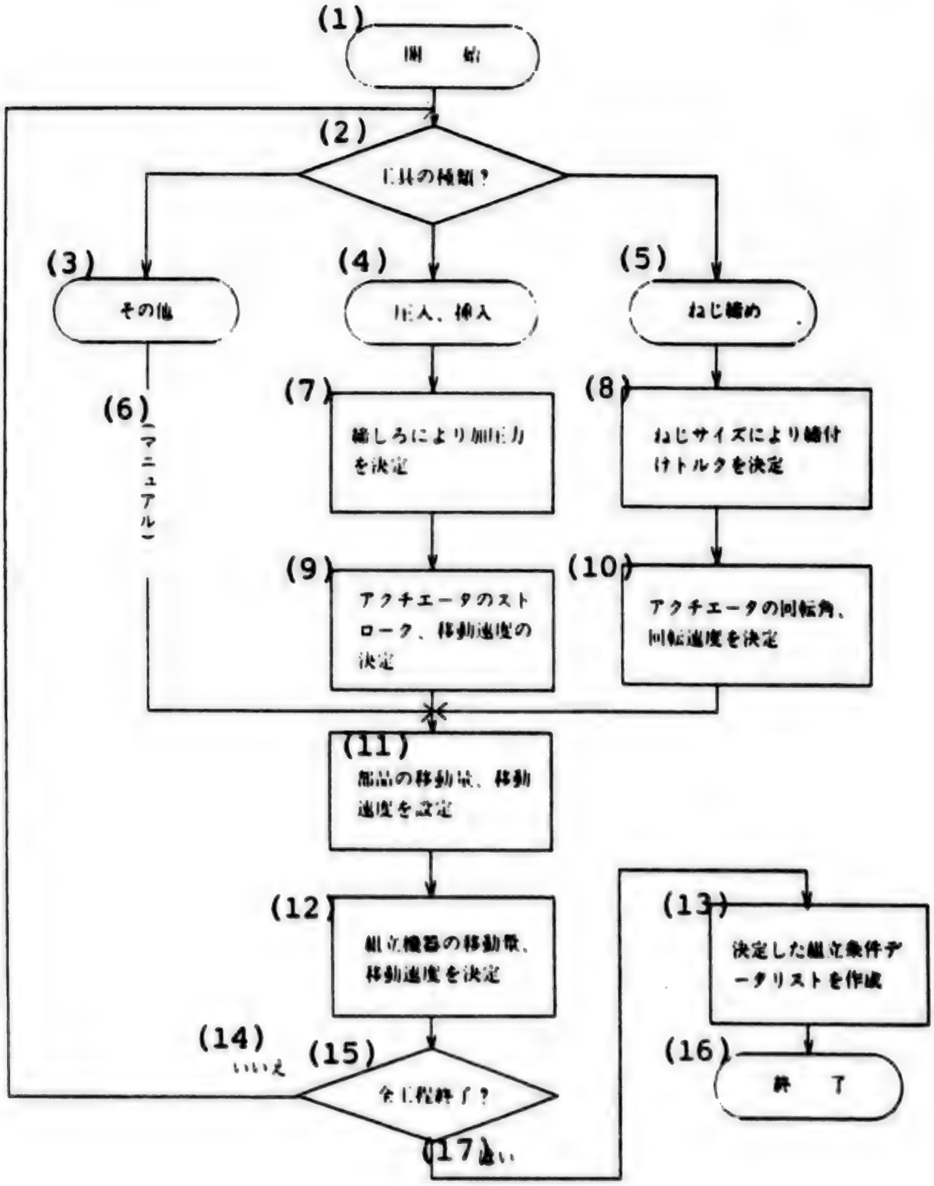
Assembly condition determination involves the determination of job conditions for each assembly job, such as press fitting conditions (press fitting, pressure cycles, etc.), positioning precision, or screw tightening torque. The data input for this purpose include parts lists, assembly sequence lists, assembly equipment, jigs, and tools, assembly sequences, and job tools. Then, based on the assembly condition setting criteria and referencing the assembly equipment data, the positioning precision, stroke, speed of movement, and job conditions (pressure applied, pressing cycle, tightening torque, etc.) are determined for each job. In Figure 3.36 is given an example of the process flow for the assembly condition determination operation. Should any irregularities occur during assembly condition determination, correctional data are fed back to the assembly procedure design stage. Other correctional data may be fed back, moreover, depending on the outcome of the level-3.7 assembly simulation.

Key to Figure 3.36:

1. Start
2. Tool type?
3. Other
4. Press fitting, insertion
5. Screw tightening
6. (Manual)
7. Determination of pressure to apply according to interference
8. Determination of tightening torque according to screw size
9. Determination of actuator stroke and speed of movement
10. Determination of actuator angle of rotation and speed of rotation
11. Determination of parts movement quantities and movement speeds
12. Determination of assembly equipment movement quantities and speeds

13. Listing of determined assembly condition data
14. No
15. All procedures finished?
16. End
17. Yes

Figure 3.36 Assembly Condition Determination



(5) Assembly Job Routing (Level 4.14)

(Input)

Parts lists
Assembly sequence lists
Assembly equipment, jigs, and tools used
Assembly job sequences
Job tools
Assembly job environment data

(Output)

Assembly job routes

(Reference Data)

Inventory control data on standard and fabricated parts
Assembly equipment data

(Processing)

Assembly job routing entails the drafting of assembly parts conveyance routes and of movement routes for assembly equipment, jigs, and tools. The data input for this purpose include parts lists, assembly sequence lists, assembly equipment, jigs, and tools used, job sequences, and job tools. The data referenced include inventory control data on standard and fabricated parts, inventory control data on job tools, and assembly equipment data. Then the routes for conveyor equipment (unmanned carrier vehicles are used as a rule, but the use of cranes and hoists must also be allowed for) to transport the parts, jigs, and tools to the assembly equipment for each order of assembly are drafted. Also drafted are the job movement routes of assembly equipment, jigs, and tools for the assembly job. The process flow is diagrammed in Figure 3.37.

Key to Figure 3.37:

1.	Start	2.	Assembly?
3.	No	4.	Yes
5.	Buffer station?	6.	No

7. Determination of transport routing for parts and job tools from buffer station
8. Determination of transport routing for parts and job tools from holding area(s)

9.	Tool change[?]	10.	No
11.	Yes		

Figure 3.37 Assembly Job Routing

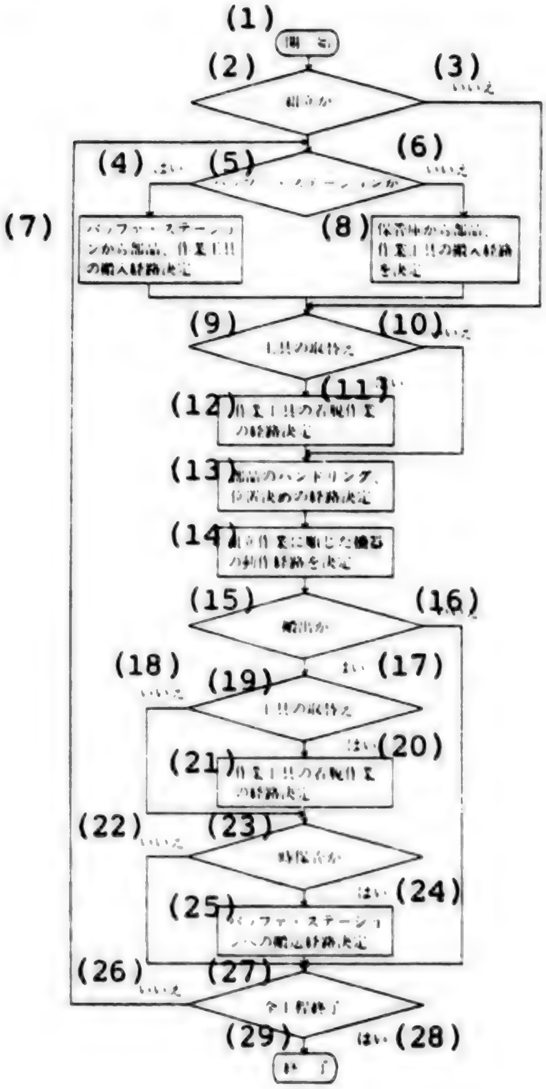
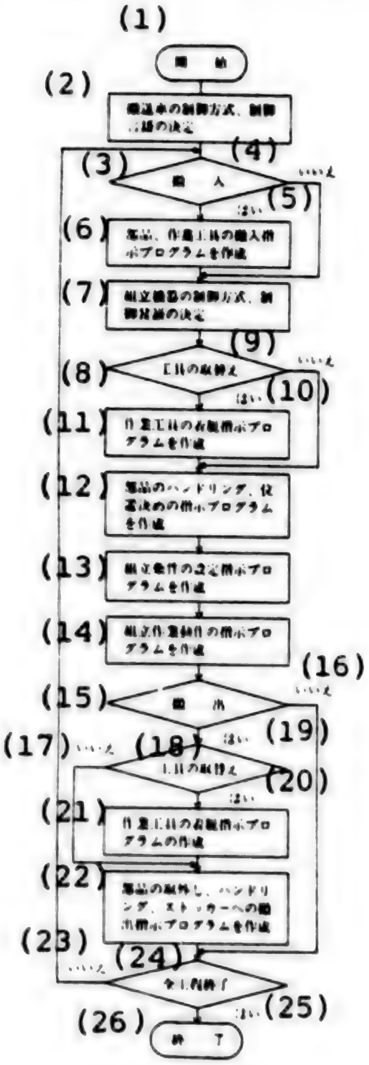


Figure 3.38 Assembly Equipment Control Programming



12. Determination of routing for job tool attachment/detachment operation
13. Determination of routing for parts handling and positioning
14. Determination of movement routes for equipment following assembly job
15. Outgoing?
16. No
17. Yes
18. No
19. Tool change[?]
20. Yes
22. No
23. Temporary storage?
24. Yes
25. Determination of routing for transport to buffer station
26. No
27. All procedures finished?
28. Yes
29. End

Key to Figure 3.38:

1. Start
2. Determination of carrier vehicle control mode, control language
3. In-going[?] 4. No
5. Yes
6. Programming for directing incoming conveyance of parts, job tools
7. Determination of assembly equipment control mode, control language
8. Tool change[?] 9. No
10. Yes
11. Programming for directing job tool attachment/detachment
12. Programming for directing parts handling, positioning
13. Programming for setting assembly conditions
14. Programming for directing assembly job movements
15. Outgoing[?] 16. No
17. No 18. Tool change[?]
19. Yes 20. Yes
21. Programming for directing job tool attachment/detachment
22. Programming for directing parts detachment, handling, and conveyance out to stocker
23. No. 24. All procedures finished[?]
25. Yes 26. End

(6) Assembly Equipment Control Programming (Level 4.15)

(Input)

Assembly order lists
Assembly equipment, jigs, and tools used
Job tools
Assembly conditions
Assembly job routes

(Output)

Assembly equipment control programs

(Reference Data)

Inventory control data for standard and fabricated parts
Inventory control data for job tools
Assembly equipment data

(Processing)

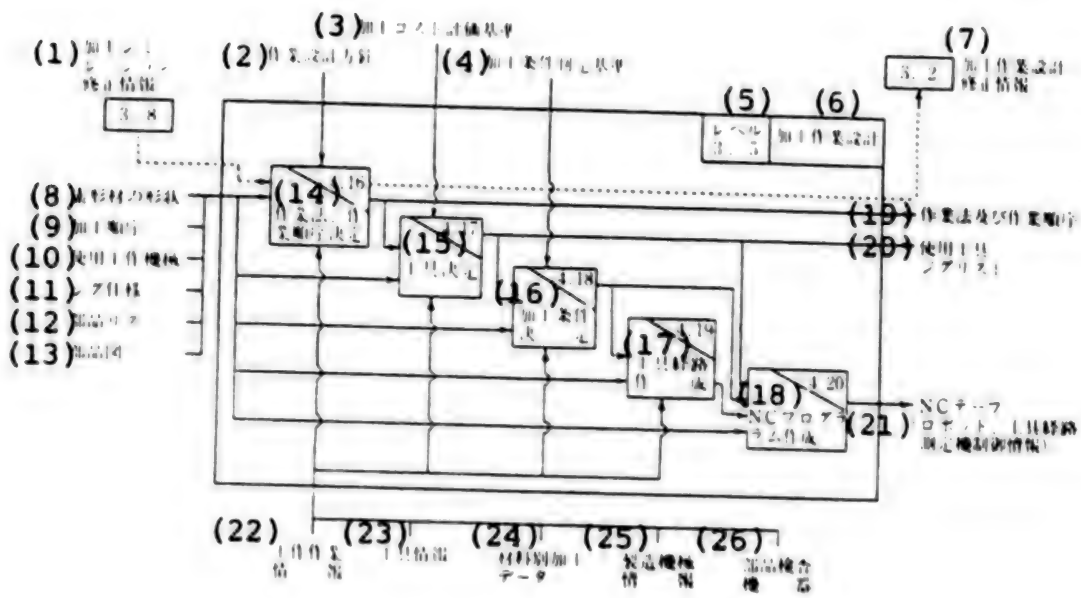
Assembly equipment control programming is the production of control programs, based on the assembly equipment control language specifications, giving consideration to the assembly equipment control mode, number of control axes, range of movement, and precision.

The data input for this purpose include assembly sequence lists, assembly equipment, jigs, and tools used, job tools, assembly conditions, and assembly job routes. The data referenced include inventory control data on standard and fabricated parts, inventory control data on job tools, and assembly equipment data. The programs produced include, for every assembly sequence, programs to transport the assembly parts and assembly equipment, programs to direct the conveyance of the jigs and tools used to the assembly equipment, and assembly equipment control programs for the assembly jobs. An example of the process flow in preparing an assembly equipment control program is diagrammed in Figure 3.38.

3.5.2 Process Job Design (Level 3.5)

Process job design, as indicated in Figure 3.39, is made up of five process units, namely job method and job sequence determination, tool determination, machining/processing condition determination, tool routing, and NC program creation.

Figure 3.39 Process Job Design



Key:

1. Process simulation correctional data
2. Job design guidelines
3. Process cost evaluation criteria
4. Process condition judgment criteria
5. Level 3.5
6. Process job design
7. Process job design correctional data
8. Stock material shapes
9. Process order
10. Machine tools used
11. Jig specifications

12. Parts lists 13. Parts drawings
14. Determination of job method, job order
15. Tool determination
16. Process conditions determination
17. Tool routing 18. NC programming
19. Job method and job order 20. List of tools and jigs used
21. NC tape (data on robots, control of measurement devices for tool routes)
22. Machining job data 23. Tool data
24. Process data for each type of material
25. Manufacturing machine data 26. Parts inspection instruments

(1) Determination of Job Method, Job Sequence (Level 4.16)

(Input)

Parts lists (part name, drawing number, material made of, tolerances, shape, cost, etc.)
Stock material shapes, dimensions, precisions (including similar products, shapes, costs, etc.)
Machine tools used (name, performance characteristics, bed area, bit diameter and travel limitations, fixed tool slots, presence and positions of any holes, etc.)
Jig specifications (including fixing methods, etc.)

(Output)

Job methods and job order

(Reference Data)

Machining job data (data on pattern and positions in which stock materials are attached to machines, position readout data on material being machined, job order data according to process pattern, tool start position data, etc.)
Manufacturing machine data (specifications for each manufacturing machine, machine precision, rigidity, speed of main drive shaft, list of tools supported, etc.)

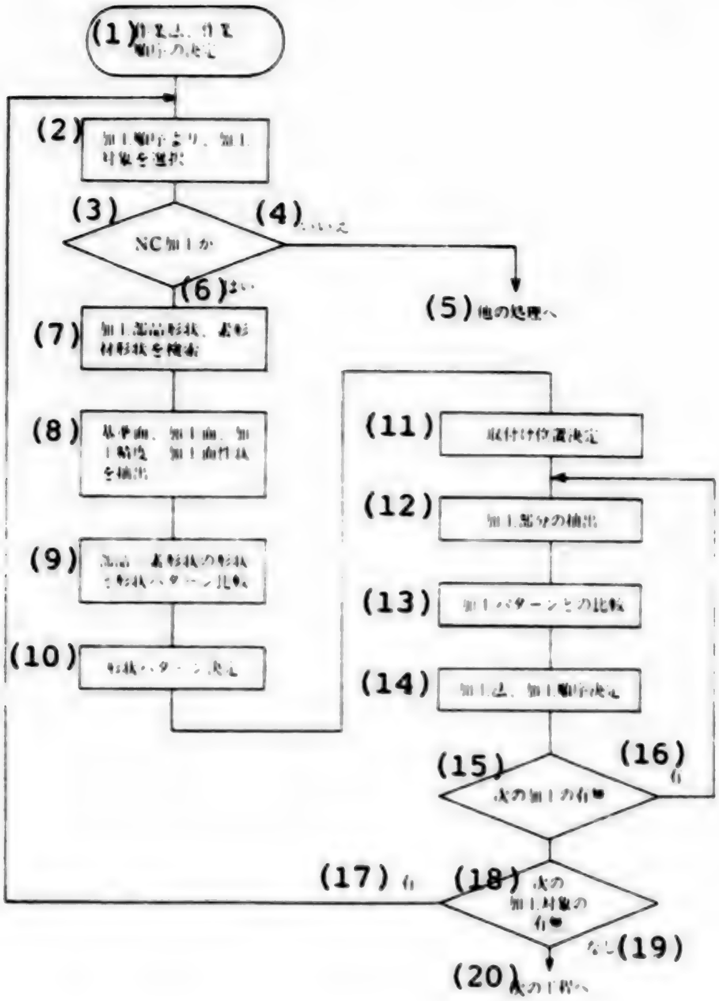
(Control Data)

Job design guidelines

(Processing)

Die fabrication jobs include various operations such as machining, hand work, heat treatment, and welding. We are here concerned with NC machining/processing, as indicated in the flowchart in Figure 3.40. Jobs other than NC processing will not be discussed here.

Figure 3.40 Flowchart for Determining Job Method, Job Order



Key:

1. Determine job method and job order
2. Select things to be machined/processed from machining/processing order
3. NC machining/processing?   4. No
5. To other process   6. Yes
7. Search for shapes of parts to be processed and stock materials
8. Extract standard surfaces, machine/process surfaces, machine/process precision, machine/process surface properties
9. Compare shapes of parts and stock materials with shape patterns
10. Determine shape patterns   11. Determine attachment positions
12. Extract portions to be machined/processed
13. Compare with machine/process patterns
14. Determine machine/process methods and order
15. Is there another process?   16. Yes

17. Yes
18. Is there something else to be machined/processed?
19. No 20. To next procedure

The parts which make up a die can be divided into two categories, namely those which are available on the commercial market, and those which must be machined and fabricated, either in house or by an outside shop.

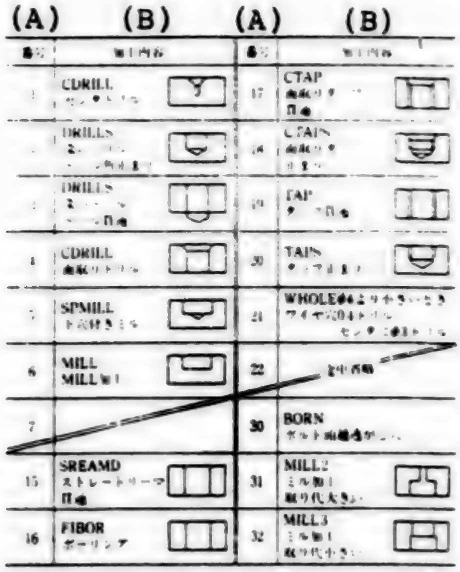
In the processing stage called "determination of job method and job order," the parts which need to be fabricated come into view. The items to be machined/processed are selected according to the process order determined at level 3.2, and the job method and order are determined. In this processing stage, the machined/processed parts or stock material shapes are searched and the machine/process surface properties (standard surfaces, portions to be machined/processed, machining/processing precision, surface roughness, etc.) necessary for implementing the machining/processing are extracted.

The shape patterns to be used here are then determined, based on the above data, and comparing reference data concerning existing patterns and parts and stock material shapes. The specific positions to be fixed are also determined. The attachment methods and attachment order were determined at level 3.2.

In any given part to be machined/processed, there may be one or a number of locations to be machined/processed. From among these locations to be machined/processed, the portions to be machined/processed are sequentially extracted.

A comparison with the machine/process pattern is made for each location to be machined/processed. Some conceivable machine/process patterns are depicted in Figures 3.41 and 3.42.

Figure 3.41 Hole Shape Pattern Examples[3.3]



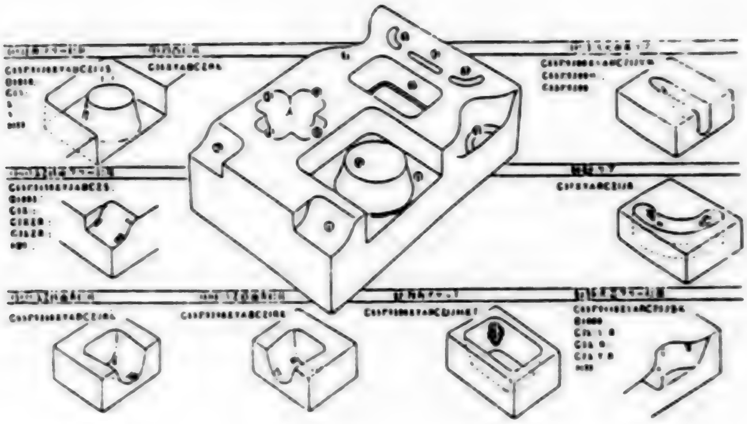
Key:

A. Number B. Machining/Processing Particulars

1. CDRILL Center drilling
2. DRILLS Deep drilling, angled drilling stop
3. DRILLS Deep drilling, through drilling
4. CDRILL Beveled drilling
5. SPMILL Milling with bottom hole
6. MILL Milling
7. [blank]
8 - 14. [omitted]
15. SREAMD Straight reamer through
16. FIBOR Boring
17. CTAP Beveled tap through
18. CTAPS Beveled tap stopped
19. TAP Tap through
20. TAPS Tap stopped
21. WHOLE When smaller than $\phi 4$, $\phi 3$ drill in center of wire hole 0.4 drilling
22 - 29. [omitted]
30. BORN Countersinking for bolt head
31. MILL2 Milling, large machining allowance
32. MILL3 Milling, small machining allowance

In Figure 3.41 are given examples of hole patterns used in die-oriented CAD/CAM systems. By inputting the hole shape and dimension data, it is easy to perform CAD shape definition for hole patterns. The sequence or procedure is designed for a single process, however, and not for multiple processes.

Figure 3.42 Examples of Milling Patterns [Japanese captions illegible]



In Figure 3.42 are given examples of milling patterns developed by one machine tool manufacturer. These processes can also be considered as a system in the same way as those in Figure 3.41.

The job sequence is determined according to the machine/process pattern for each and every machining/processing portion. When there are a number of portions to be machined/processed, however, it is necessary to edit the machining/processing methods and sequences already determined for the portions to be machined/processed in order to perform the job efficiently. When this editing has been performed, processing at this level is complete.

(2) Tool Determination (Level 4.17)

(Input)

Parts drawings (shapes, dimensions, and precisions for parts to be machined/processed)
Stock materials (stock material composition, shapes, dimensions, etc.)
Machine tools used
Jig specifications
Job methods and order

(Output)

List of tools used (tool specifications, standard tool types, order of tool usage)
List of jigs used

(Reference Data)

Tool data (standard tool lists)
Process data for each type of material (optimum tool specifications for each type and process)
Manufacturing machine data (specifications for each manufacturing machine, machine precision, rigidity, power, main shaft speed, and list of tools supported)

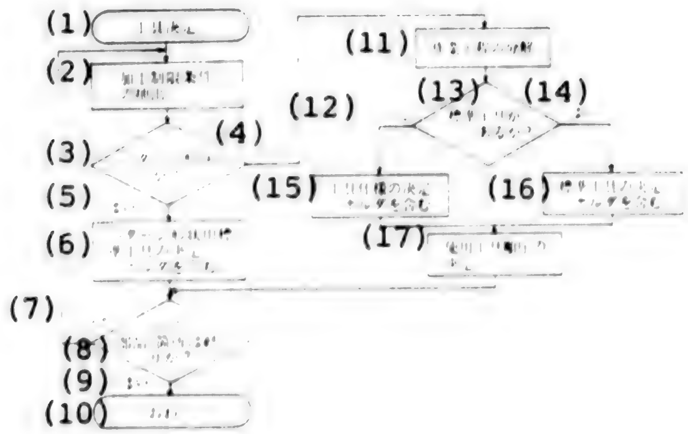
(Control Data)

Process cost evaluation criteria (to minimize costs relative to delivery dates and machining/processing precision)

(Processing)

In terms of tool determination processing, we here consider the example of the machining center. In Figure 3.43 the flow for this tool determination is diagrammed. First data is input, including the shapes and dimensions of the machined/processed parts and stock materials and the types of machine tools used. Then, while referencing tool data and manufacturing machine data, the power and main shaft speed ranges for the machine tools used are extracted, along with the range of tool dimensions which can be used, the minimum radius of curvature for concavities, machine/process lengths, and other processing control conditions.

Figure 3.43 Tool Determination Flowchart



Key:

1. Tool determination
2. Extraction of machining/processing control conditions
3. Pattern shape? 4. No
5. Yes

6. Determination of standard tools for pattern shapes, including tool holders
7. No
8. Is this the last machining/processing part and location?
9. Yes
10. End
11. Job procedure breakdown
12. No
13. Are standard tools available?
14. Yes
15. Determination of tool specifications, including tool holders
16. Determination of standard tools, including tool holders
17. Determination of order of tools used

We next check to see whether the pattern shapes are available for the job method and order determined at level 4.16, taking stock material composition and machining/processing limitations into account. If they are available, the standard tool sets (including tool holders) prepared for the pattern shapes are determined.

If they are not available, one must determine whether or not usable standard tools are available for each minimum job unit. If they are available, these standard tools are selected. If they are not available, the tool specifications (type, composition, shape, dimensions) and tool holder specifications are determined. When standard and non-standard tools are used together in the same job procedure, an order of use must be determined for them.

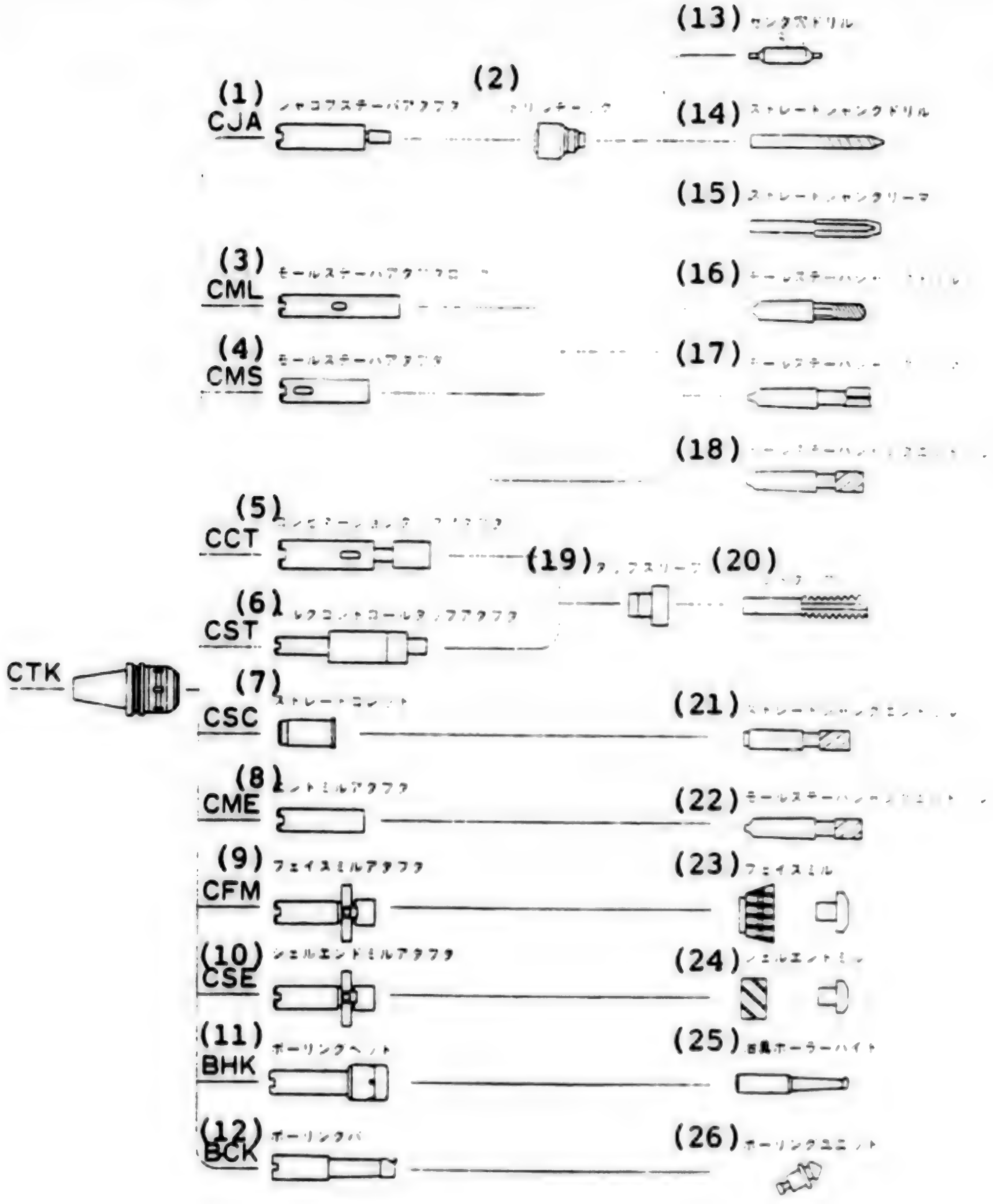
The above process is repeated for each machining/processing location and part. After all of the tools have been decided on, the job method and order for these tools are reedited.

During the course of this processing operation, the control data are used, and tool determinations are made so as to minimize processing costs while keeping the delivery dates and machining/processing precision within stipulated ranges. In Figure 3.44 is given an example of a machining center tooling system, in Figure 3.45 an example of a tool file, and in Figure 3.46 examples of tool parameter designations.

Key to Figure 3.44:

1. Jacobs taper adapter
2. Drill chuck
3. Morse taper adapter long
4. Morse taper adapter
5. Combination tap adapter
6. Torque control tap adapter
7. Straight collet
8. End mill adapter
9. Face mill adapter
10. Shell end mill adapter
11. Boring head
12. Boring bar
13. Centerhole drill
14. Straight shank drill
15. Straight shank reamer
16. Morse taper shank drill
17. Morse taper shank reamer
18. Morse taper shank end mill

Figure 3.44 Machining Center Tooling Example (from Toshiba Tungalloy catalog)



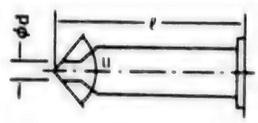
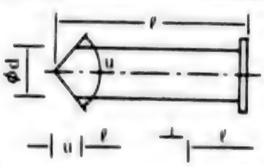
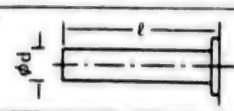
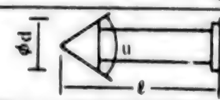
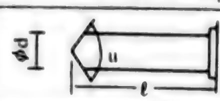
19. Tap sleeve
20. Hand tap
21. Straight shank end mill
22. Morse taper shank end mill
23. Face mill
24. Shell end mill
25. Jig borer cutting tool
26. Boring unit

Figure 3.45 Tool File Example (from NEC CAE-2D catalog)

```
Type, Name                          Movement Type, Coolant, Shaft Speed
 of Tool       Dimensions              Feed Speed, Tool Number

TOLF
T  1/MIL.    2.   40.         M. 12  . A. MST. S.  60. F.  30. T.  1.  1
T  2/MIL.    4.   40.         M. 12  . A. MST. S.  60. F.  30. T.  2.  2
T  3/MIL.    6.   40.         M. 12  . A. MST. S.  60. F.  30. T.  3.  3
T  4/MIL.    8.   40.         M. 12  . A. MST. S.  60. F.  30. T.  4.  4
T  5/MIL.   10.   40.         M. 12  . A. MST. S.  60. F.  30. T.  5.  5
T11/CFT.    20.   80.         M. 12  . A. FLD. S.  60. F. 100. T. 11. 11
T12/CFT.    30.   80.   60.   M. 12  . A. FLD. S.  60. F. 100. T. 12. 12
T13/CFT.    40.   80.   90.   M. 12  . A. FLD. S.  60. F. 100. T. 13. 13
T14/CFT.    50.   80.  120.   M. 12  . A. FLD. S.  60. F. 100. T.
T21/CDR.     1. 250.          M. 1.    A. OFF. S.  60.                58. 58
T22/CDR.     2. 250.          M. 1.    A.          58. F.  80. T. 59. 59
T23/CDR.     3. 250.                          . S.  25. F.   5. T. 61. 61
T24/CDR.                2. 5. M. 2. 1         . S.  25. F.   5. T. 62. 62
     REM.    3. 260.     5. M. 2. 1           . S.  25. F.   5. T. 63. 63
T64/REM.     4. 260.     5. M. 2. 1           . S.  25. F.   5. T. 64. 64
T65/REM.     5. 260.     5. M. 2. 1           . S.  25. F.   5. T. 65. 65
T66/REM.     6. 260.     5. M. 2. 1           . S.  25. F.   5. T. 66. 66
T67/REM.     8. 260.     5. M. 2. 1           . S.  25. F.   5. T. 67. 67
T68/REM.    10. 260.     2. M. 2. 1           . S.  25. F.   5. T. 68. 68
T69/REM.    20. 260.     2. M. 2. 1           . S.  25. F.   5. T. 69. 69
T71/CST.     1. 260.        M. 5. A. FLD      . S.  25. F. 180. T. 71. 71
T72/CST.     2. 260.        M. 5. A. FLD      . S.  25. F. 180. T. 72. 72
T73/CST.     3. 260.        M. 5. A. FLD      . S.  25. F. 180. T. 73. 73
```

Figure 3.46 Tool Types & Dimensional Parameters (from NEC CAE-2D catalog)

(1) 名称	(2) 工具種類	(3) 寸法パラメータ			(7) ○：必ず指定 △：省略可
		(4) 工具径 d	(5) 工具長 ℓ	(6) 食付部または先端角 u	
(8) センタドリル	CDR			△ (118°)	
(9) ドリル	DRL			△ (118°)	
(10) ミーリング	MIL				
(11) チャンファ	CFT			△ (90°)	
(12) カウンタシンク	CST			△ (118°)	

Key:

1. Name
2. Tool type
3. Dimensional parameters
4. Tool diameter d
5. Tool length *l*
6. Chamfer or tip angle u
7. o: Always designated Δ: May be omitted
8. Center drill
9. Drill
10. Milling
11. Chamfer
12. Countersink

(3) Machining/Processing Condition Determination (Level 4.18)

(Input)

Parts drawings (shapes, dimensions, and precision of process parts)
Stock material shapes (stock material composition, shapes, dimensions)
Machine tools used
Jig specifications
Job methods, job order
List of tools used

(Output)

Process condition data for each tool (main shaft speed, cutting depth, feed, etc.)

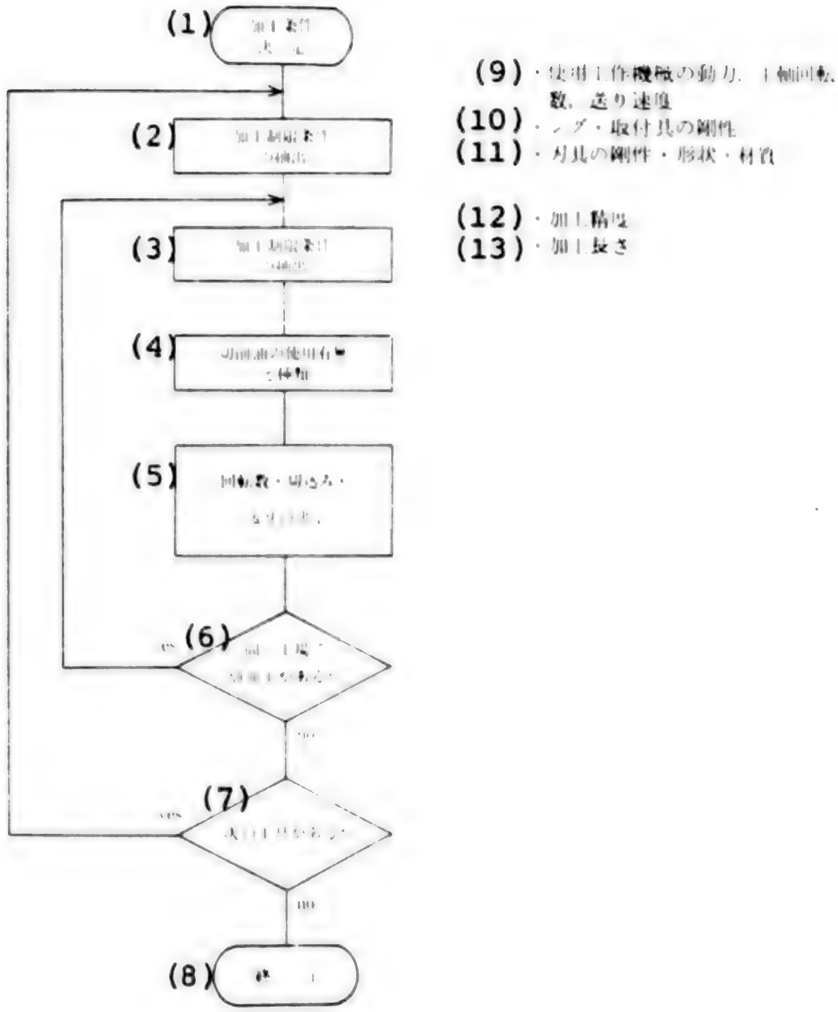
(Reference Data)

Tool data (standard tool lists)
Machining/processing data for each material (specifications for each manufacturing machine, machine precision, rigidity, power, main axis speed, list of tools supported, etc.)

(Processing)

With regard to machining/processing determination, in Figure 3.47 is given a flowchart drawn up for cutting processes. The data input in the process stage include both data output from processing procedure design (level 3.2), namely the process parts drawings needed, stock material composition, shape, and dimensions, job methods and order, machine tools used, and jig specifications and attachment positions, and data output from tool determination (level 4.17), namely lists of tools used and other tool data. Machining/processing conditions are determined, following the processing conditions judgment criteria, and referencing machining/processing equipment data, tool data, stock material composition data, machining/processing precision data, and finished surface roughness data. The output from this processing stage consists of machining/processing condition data. If necessary, lists of tool processing conditions are also output.

Figure 3.47 Machining/Processing Condition Determination Flowchart



Key to Figure 3.47:

1. Processing condition determination
2. Extraction of processing control conditions
3. Extraction of Processing Control Conditions
4. Determination of type of cutting oil to use, if any
5. Determination of rotational speed, cutting depth, feed
6. Are different processes available at the same plant?
7. Is there another tool? 8. End

In determining the machining/processing conditions, it is preferable that reference data for each piece of machining/processing equipment be loaded beforehand into a database. The volume of data becomes enormous, so one may

prepare standard machining/processing data files and then apply correctional coefficients for each piece of equipment.

The data referenced include machine data, tool data, stock material composition data, machining/processing precision data, finished surface roughness data, and machining/processing condition data. Examples of such data are given in Figure 3.48[3,4] (relationship between cutting speed and machining precision), Figure 3.49[3,4] (relationship between cutting depth and machining precision, and Figure 3.49[3,4] (relationship between feed and machining precision).

Fig 3.48 Cutting Speed vs Precision in End Mill Cutting

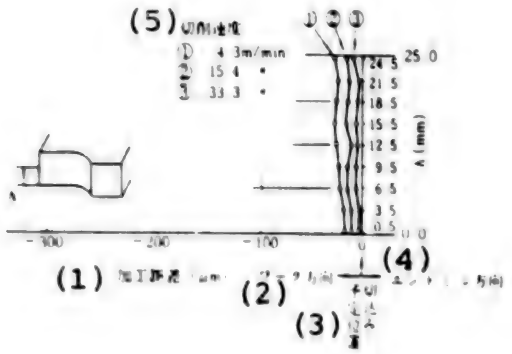
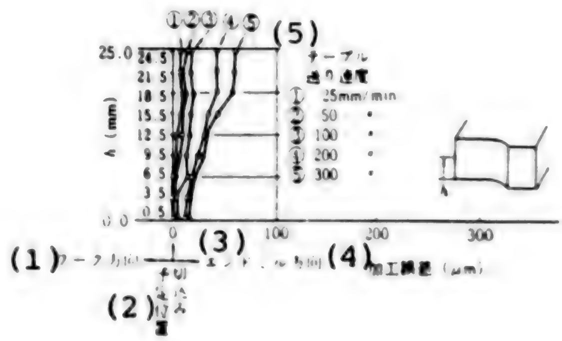


Fig 3.50 Feed vs Precision in End Mill Cutting



Key to Figure 3.48:

1. Machining error (μm)
2. Work direction
3. Predicted position of cut depth
4. End mill direction
5. Cutting speed

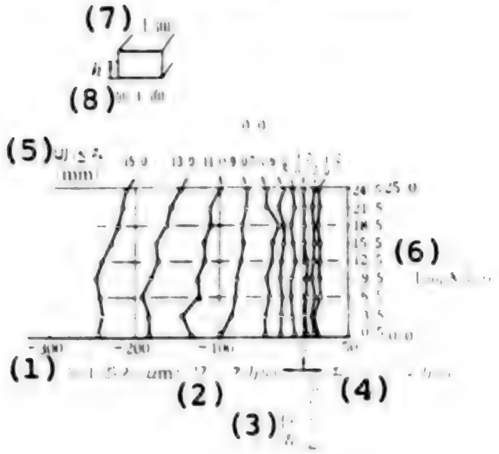
Cutting speed characteristics
(upward cutting)
Work: Cast iron F C 25
Length 100 x 25 mm
Tool: End mill ϕ31, 4-blade, SKH3
Length protruding from chuck: 55 mm
Feed: 0.08 mm/knife
Radial direction cut-in: 6 mm
Axial direction cut-in: 25 mm
Cutting-oil cuts: None
Machine tool: Vertical milling machine (remove work VH type)

Key to Figure 3.50:

1. Work direction
2. Predicted position of cut depth
3. End mill direction
4. Machining error
5. Table feed speed

Feed speed characteristics
(upward cutting)
Tool: End mill ϕ32, 4-blade, SKH3
Length protruding from chuck: 70 mm
Feed speed: 0.012 mm/knife (25mm/min) to 0.14 mm/knife (399 mm/min)
Cutting speed: 33 m/min
Radial direction cut-in: 3 mm

Fig 3.49 Cut-Depth, Precision in End Mill Cutting



Key:

1. Machining error
2. Work direction
3. Predicted machining position
4. End mill direction
5. Cutting depth (mm)
6. Upward cutting
7. Upper surface
8. Process (machining) surface

Cutting Depth Effects (with ϕ20 end mill) Radial cut depth: 0.5 - 15 mm
Cutting speed: 33 m/min
Feed: 0.08 mm/knife
Other conditions same as Fig 2.4F14

(4) Tool Routing (Level 4.19)

(Input)

Parts drawings (process parts shape, dimensions, precision)
Stock material shapes (stock material composition, shape, dimensions)
Machine tools used
Jig specifications
Job methods, job order

(Output)

CL data
Process time data

(Reference Data)

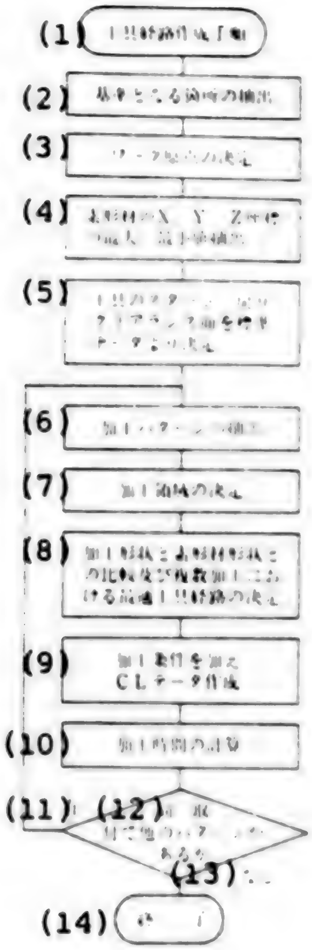
Manufacturing machine data (specifications for each manufacturing machine, machine precision, rigidity, power, main shaft speed, list of tools supported, etc.)
Tool data (standard tool lists)
Machining/processing data for each material (proper tool specifications for each material and each process)
Process pattern data
Tool start position standard data
Machining/processing precision, surface properties data

(Processing)

This processing stage is flowcharted in Figure 3.51. Based on the standard surface, the work origin, tool start, and return positions are determined. The tool routes are also determined, after comparing the process parts shapes and process patterns. The cutting volume and cutting width are also

determined, based on the machining/processing condition data for each tool. The tool routes are output as CL data. Also included in these data are such machining/processing conditions as the feed speeds and main shaft speeds.

Figure 3.51 Tool Routing Sequence Flowchart



Key:

1. Tool routing sequence
2. Extraction of locations which will provide standards
3. Determination of work origin
4. Extraction of maximum and minimum values of X, Y, and Z coordinates for stock material
5. Determination of tool start, return, and clearance surface from standard data
6. Extraction of machining/processing patterns
7. Determination of machining/processing regions

8. Comparison of machining/processing shapes and stock material shapes, and determination of optimal tool routes in multiple processes
9. Preparation of CL data, with addition of machining/processing conditions
10. Calculation of machining/processing times
11. Yes
12. Is there another pattern for the same attachment [position]?
13. No 14. End

(5) NC Programming (Level 4.20)

(Input)

CL data
Machine tools used
List of tools used

(Output)

NC programs
NC machining/processing data (tooling data, etc.)

(Reference Data)

Manufacturing machine data (specifications for each manufacturing machine, machine precision, rigidity, power, main shaft speed, list of tools supported, NC control equipment data, etc.)
Tool data (standard tool lists)

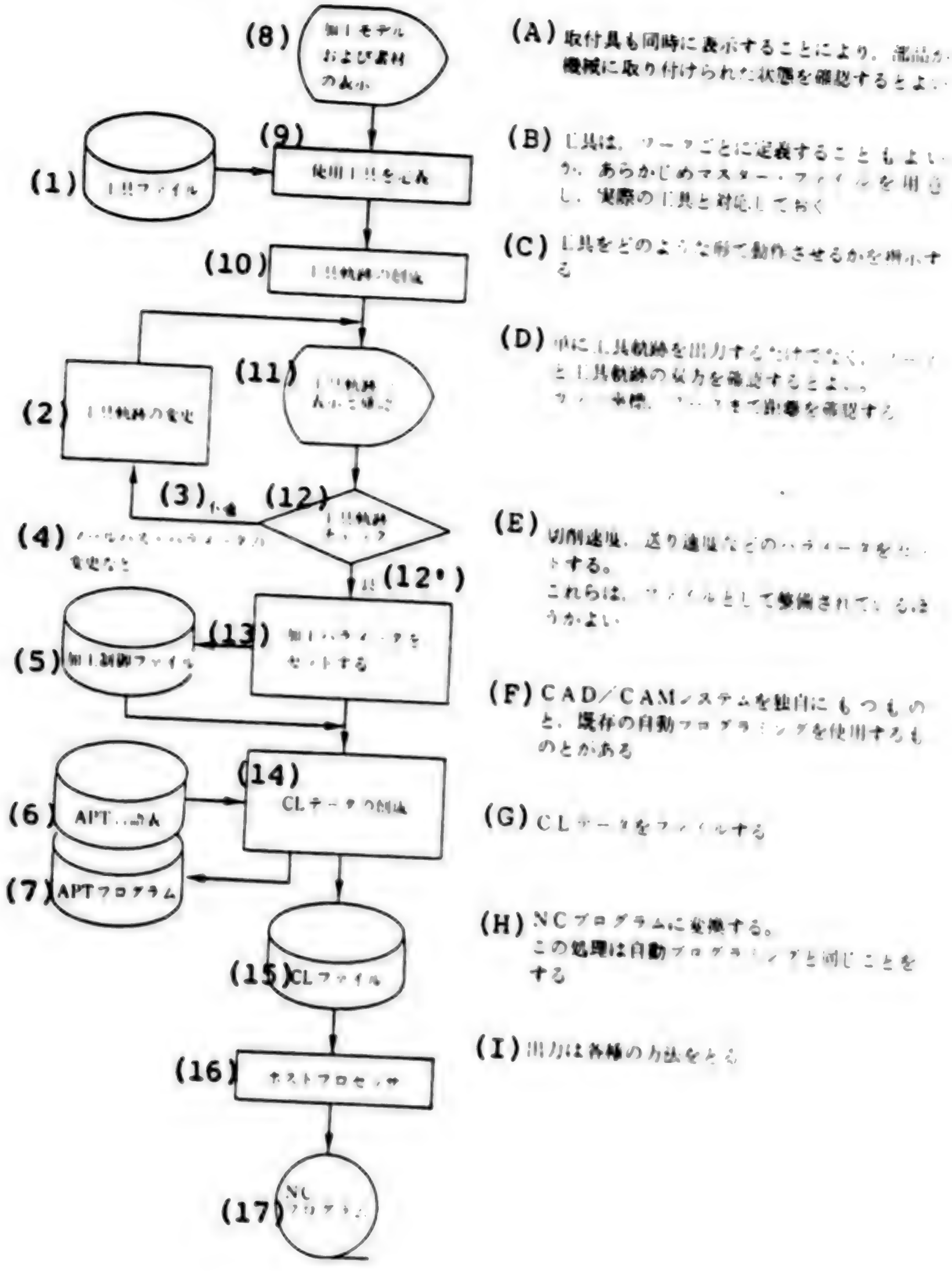
(Processing)

This processing stage is flowcharted in Figure 3.52.[3,5] CL data are converted to NC programs via a post-processor which handles NC equipment data for machine tools. Necessary incidental machining/processing data are also put together and output at this stage.

Key to Figure 3.52:

1. Tool files 2. Tool path change
3. Unsuitable 4. Changes in tool-path parameters
5. Machining/processing control file
6. APT language tables 7. APT programs
8. Display of process model and material
9. Definition of tools used 10. Creation of tool paths
11. Tool path display verification
12. Tool path check 12'. Good
13. Set machining/processing parameters

Figure 3.52   Flowchart of NC Programming Sequence

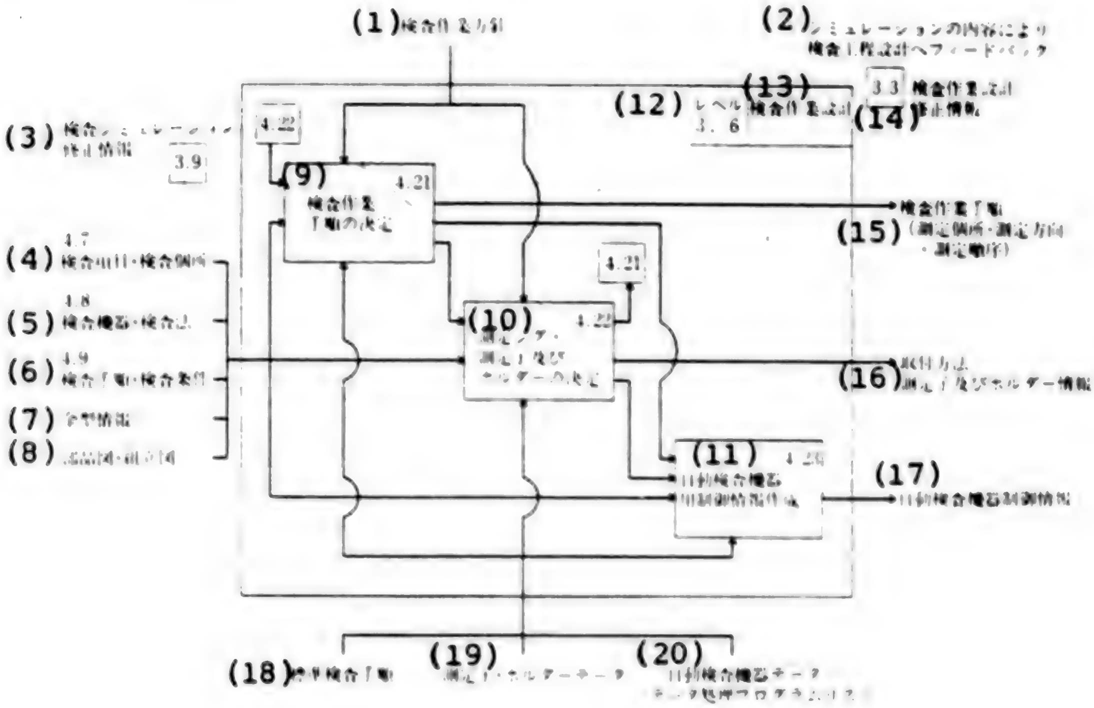


14. Create CL data
15. CL files
16. Post-processor
17. NC programs

A. It is also good to verify the condition in which parts are attached to the machines by simultaneously displaying the fasteners.

B. Tools may be defined for each piece of work, but it is better to create a master file beforehand and have this correspond to the actual tools.
C. Indicate in what fashion tools will be caused to move.
D. It is good to verify both the work and tool paths, and not just output the tool paths alone.
   Verify the cut coordinates and distances to work.
E. Set such parameters as cutting speed and feed speed.
   It is better to have these [parameters] placed in files.
F. There are two types, namely those which have their own CAD/CAM systems, and those which use existing automatic programming.
G. File CL data.
H. Convert to NC program.
   This process does the same things that automatic programming does.
I. Output can take various methods.

Figure 3.53 Inspection Job Design (Level 3.6)



Key:

1. Inspection job guidelines
2. Feed back to inspection procedure design according to simulation content
3. Inspection simulation correctional data
4. Inspection criteria, inspection locations
5. Inspection instruments, inspection methods
6. Inspection sequences, inspection conditions

7. Die data 8. Parts drawings, assembly diagrams
9. Determination of inspection job sequences
10. Determination of measurement jigs, probes, and holders
11. Determination of control data for automatic inspection instruments
12. Level 3.6 13. Inspection job design
14. Inspection job design correctional data
15. Inspection job sequences (measurement locations, direction, order)
16. Attachment methods, measurement probe and holder data
17. Automatic inspection instrument control data
18. Standard inspection sequences
19. Measurement probe, holder data
20. Automatic inspection instrument data
    Data processing program lists

3.5.3 Inspection Job Design (Level 3.6)

As may be seen in Figure 3.53, inspection job design is made up of three processes, namely the determination of inspection job sequences, the determination of measuring probes and holders, and, when automatic inspection equipment is selected, the preparation of control data for that equipment.

(1) Inspection Job Sequence Determination (Level 4.21)

(Input)

Die data
Assembly diagrams, parts drawings
Inspection categories, inspection locations
Inspection instruments, inspection methods
Inspection conditions, inspection sequences

(Output)

Inspection job sequences (measurement locations, measurement direction, measurement order)

(Reference Data)

Standard inspection sequences
Measurement, holder data
Automatic inspection equipment data, data processing program lists

(Control Data)

Inspection job guidelines

(Processing)

What is here discussed as inspection job sequences refers to a series of measurement operation sequences which are to be implemented for each inspection category, based on the methods of using the inspection instruments.

The data input for the purpose of determining the inspection job sequences include die data, assembly diagrams, parts drawings, the inspection categories and inspection locations output at level 4.7, the inspection instruments and methods output at level 4.8, and the inspection conditions and sequences output at level 4.9. Depending on the results of determinations on measurement jigs, measurement probes, and holders, correctional data pertaining thereto may be fed back. Other correctional data may be fed back depending on the inspection simulation results.

Whereas the inspection job sequences for specialized equipment tend to be relatively fixed, there is a high degree of flexibility in the inspection job sequences for general-purpose equipment. Hence a number of different sequences are conceivable as inspection job sequences. As one example, we here consider measurements using three-dimensional measuring devices. The making of dies frequently involves operations in which many holes are cut into plate. We will now describe the determination of a job sequence for the case of measuring the pitch between such holes.

Firstly, there are generally no restrictions on the method of securing the material that is to be measured with a three-dimensional measuring device, so long as the probe(s) can contact all locations to be measured. In other words, it is only necessary to attach the material so that the probe(s) will make contact with all of the surfaces and/or holes to be measured.

Next, a coordinate system is set for the material to be measured. The common sequence for this is as follows. (1) Determine the reference plane (either the XY, YZ, or ZX plane) for the material to be measured. (2) Provide reference axes inside the reference plane on the material to be measured. (3) When the origin on the material to be measured does not coincide with the origin of the reference axes, shift the reference axes to the origin on the material to be measured.

After the coordinate system has been completely established, the measurement locations (holes) on the material to be measured are sequentially measured. The order in which these holes are measured is basically discretionary. This being so, it is necessary to establish some kind of evaluation function(s) in order to determine the inspection job sequence. For example, if the total probe movement is taken as an evaluation function, then the sequence which minimizes this evaluation function will be output as output data. Such evaluation functions must be defined in the inspection job guidelines which constitute the control data. The reference data include standard inspection sequences, measurement and holder data, and automatic inspection equipment data.

Should irregularities develop in determining the inspection job sequence, data will be output and fed back to levels 4.8 and 4.9.

(2) Measurement Jig, Measurement Probe, Holder Determination (Level 4.22)

(Input)

- Inspection instruments used
- Inspection conditions
- Measurement locations
- Measurement direction
- Measurement order
- Die data
- Parts drawings
- Assembly diagrams

(Output)

- Attachment method (method of securing the work)
- Measurement jig data
- Measurement probe and holder data
- Calibration methods and calibration data

(Control Data)

- Inspection job guidelines (inspection time, inspection precision, etc.)

(Processing)

In this processing stage, the measurement jigs are determined, together with the measurement probes and holders used in the inspections, for conducting inspection jobs based on the inspection conditions and inspection sequences from level 4.9 for the inspection categories and locations determined at level 4.7, using the inspection instruments determined at level 4.8.

In determining the measurement jigs, the attachment method is determined, giving due consideration to the inspection item shape, inspection categories, and inspection direction, and using, as necessary, parallel surface plates, parallel blocks, precision vices, clamping kits, adjustment jacks, and horizontal index tables. The process flow for a measurement jig determining operation is diagrammed in Figure 3.54.

In determining the measurement probes and holders, the types of holders used are determined, giving consideration to the inspection instruments used, the inspection locations, and the inspection direction. The determination of the measurement probes to use from such data as the measurement pitch, hole diameter, and measurement precision are made, following the priority order for inspection time and inspection precision, for example, in the inspection job guidelines. The calibration method and calibration precision are also determined.

In Figure 3.55 is given a flowchart example for determining a holder which is an arm. In Figure 3.56 is given a flowchart for determining a measurement probe which is a stylus.

Fig 3.54 Measurement Jig Determination

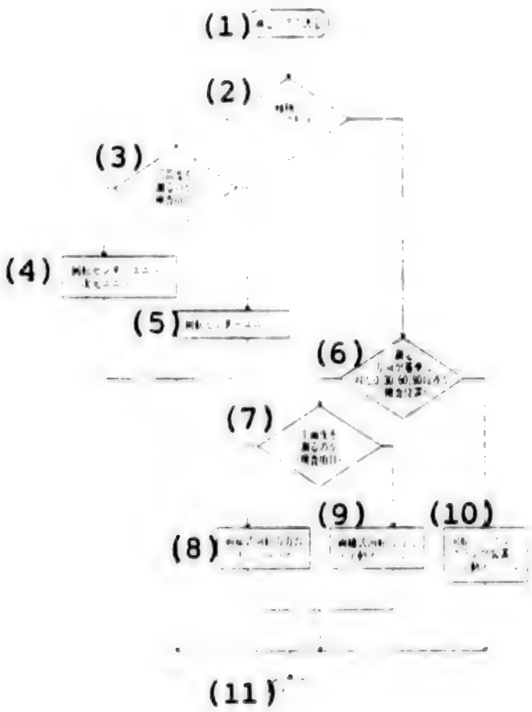
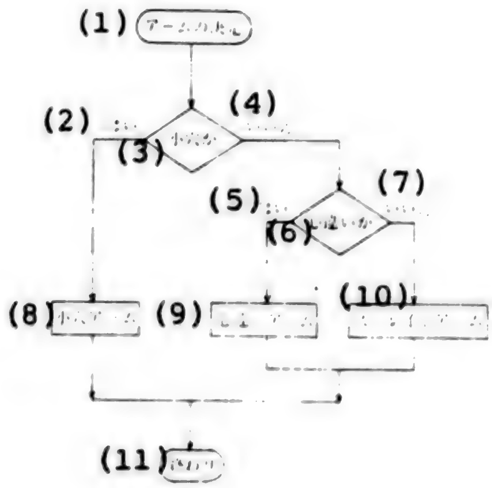


Fig 3.55 Arm Determination



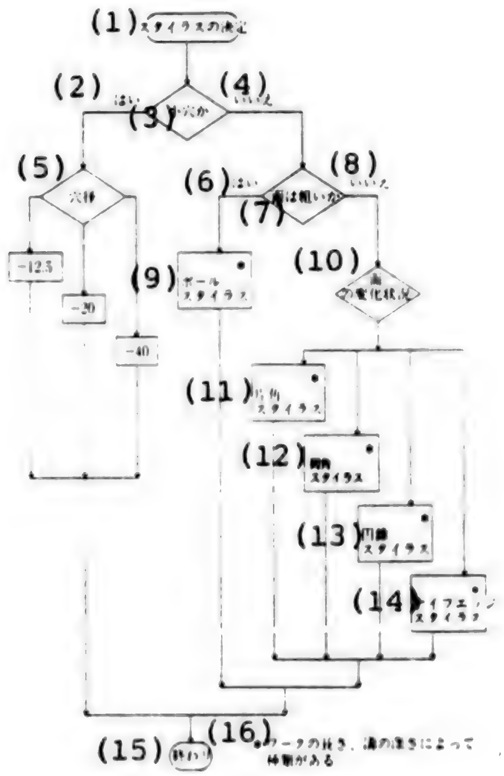
Key to Figure 3.54:

1. Measurement jig determination
2. Axial item? (work shape)
3. Will cylindricality be determined? (inspection category)
4. Turning-center unit, three-dimensional unit
5. Turning-center unit
6. Is measurement direction other than 0, 30, 60, or 90[°] offset from reference? (inspection position)
7. Will flatness be measured? (inspection category)
8. Double-tightening rotating universal table, three-dimensional unit
9. Double-tightening rotating universal table, cross-movement table
10. Rotating table, clamping device, cross-movement table
11. End

Key to Figure 3.55:

1. Arm determination
2. Yes
3. Small hole?
4. No
5. Yes
6. Far-centered?
7. No
8. Small-hole arm
9. Far-centered arm
10. Straight arm
11. End

Figure 3.56 Stylus Determination



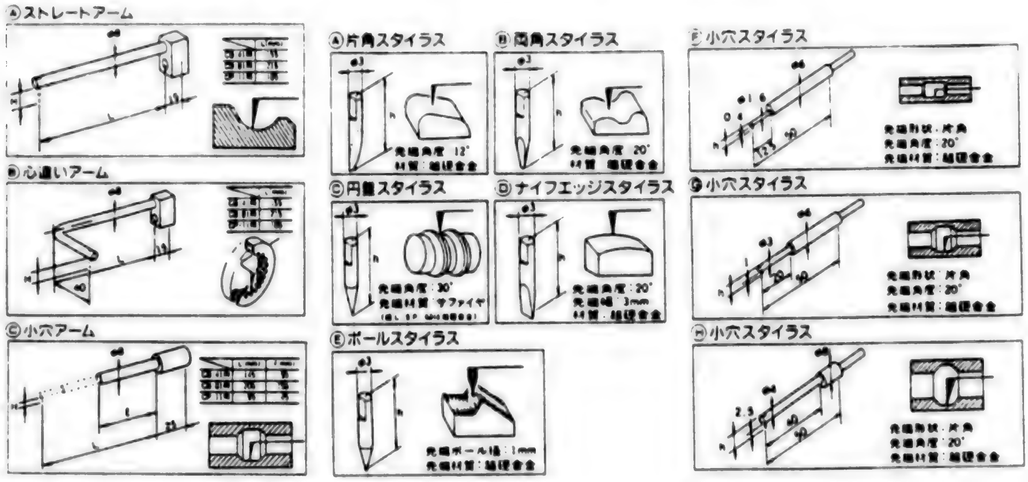
Key:

1. Stylus determination
2. Yes
3. Small hole?
4. No
5. Small diameter
6. Yes
7. Is surface rough?
8. No
9. Ball stylus
10. Surface change condition
11. Single-angle stylus
12. Double-angle stylus
13. Conical stylus
14. Knife-edge stylus
15. End
16. * Type depends on length of work, depth of groove(s).

In Figure 3.57 are depicted the types of arms and styluses used with contour-shape measurers.

Figure 3.57 Types of Arms, Styluses for Contour-Shape Measurers (from Mitsutoyo catalog)

a. Types of Arms ((A)-(C)) b. Types of Styluses ((A)-(H))



Key to Fig 3.57(a):

(A) Straight arm (B) Off-center arm (C) Small-hole arm

Key to Figure 3.57(b):

(A) Single-angle stylus
Tip angle: 12°; Tip material: Superhard alloy
(B) Double-angle stylus
Tip angle: 20°; Material: Superhard alloy
(C) Conical stylus
Tip angle: 30°; Tip material: Sapphire (superhard alloy for L, SP•63)
(D) Knife-edge stylus
Tip angle: 20°; Tip width: 3 mm; Material: Superhard alloy
(E) Ball stylus
Tip ball diameter: 1 mm; tip material: Superhard alloy
(F) Small-hole stylus
Tip shape: Single angle; Tip angle: 20°; Material: Superhard alloy
(G) Small-hole stylus
Tip shape: Single angle; Tip angle: 20°; Material: Superhard alloy
(H) Small-hole stylus
Tip shape: Single angle; Tip angle: 20°; Material: Superhard alloy

Should any irregularity develop in the inspection job sequences (which are input data) during these determinative operations, feedback data is generated and sent to level 4.21.

Should irregularities develop in the determination of the measurement jigs, measurement probes, or holders, feedback data is generated and sent back to levels 4.8 and 4.9.

Should irregularities develop in the inspection instruments, inspection conditions, or inspection sequences, feedback data are generated and sent back to level 3.3.

(3) Preparation of Control Data for Automatic Inspection Equipment (Level 4.23)

(Input)

Inspection conditions
Inspection instruments used
Inspection categories, inspection locations
Inspection sequences
Measurement locations, measurement direction
Measurement order
Measurement jig data
Measurement probe, holder data
Measurement calibration method, calibration precision
Die data
Parts drawings, assembly diagrams

(Output)

Measurement routes
Measurement programs pertaining to reading, processing measurement data
Measurement job instruction manual
Data-processing program information

(Reference Data)

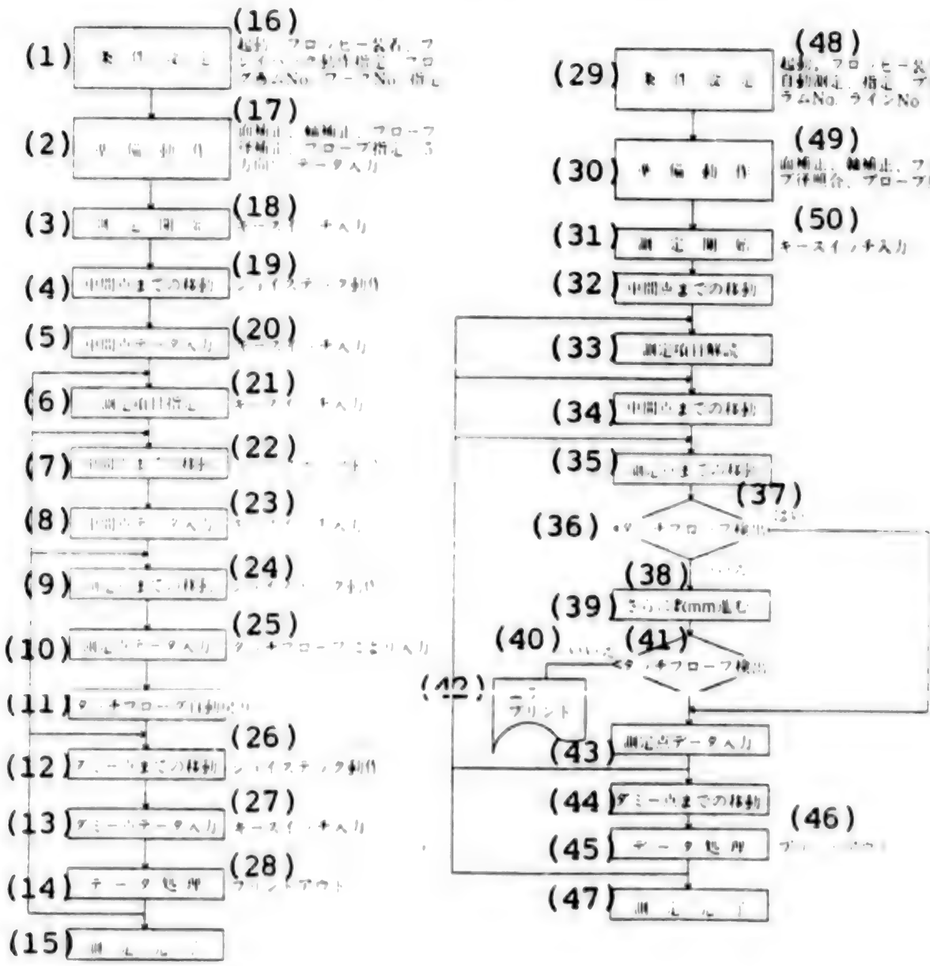
Automatic inspection equipment data
Data processing program lists

(Processing)

In this processing stage, when automatic inspection equipment has been selected as the inspection instrument(s) to be used, control data are created for using the said equipment to perform automatic inspections. In the creation of this control data, measurement routes are determined, based on the inspection categories, locations, and sequences determined at levels 4.7, 4.8, and 4.9, the measurement locations, measurement direction, and measurement order for each inspection location, data on the measurement probes and holders used, inspection item shapes, and data on the measurement

jigs used to attach the items. Data pertaining to the data processing programs used and printed instructions for the measurement jobs are also output. Finally, automatic calibration control data for the inspection devices used are also generated. In Figure 3.58 is given a typical series of flows for a measurement job in an inspection operation.

Figure 3.58 Measurement Job Flow Series (from Mitsutoyo Technical Report)



Key:

1.	Set conditions	2.	Preparatory movements
3.	Start measurement	4.	Move to center point
5.	Input center-point data	6.	Designate measurement category
7.	Move to center point	8.	Input center-point data
9.	Move to measurement point	10.	Input measurement point data
11.	Automatic return of touch probe		
12.	Move to dummy point	13.	Input dummy point data
14.	Data processing	15.	Measurement complete

16. Start. Load floppy disk, designate playback operation, program number, and work number
17. Planar correction, axial correction, probe diameter correction, probe designation (5 directions), data entry
18. Keyboard input
19. Joystick operation
20. Keyboard input
21. Keyboard input
22. Joystick operation
23. Keyboard input
24. Joystick operation
25. Input by touch probe
26. Joystick operation
27. Keyboard input
28. Printout
29. Set conditions
30. Preparatory movements
31. Start measurement
32. Move to center point
33. Interpret measurement category
34. Move to center point
35. Move to measurement point
36. Touch probe detection[?]
37. Yes
38. No
39. Advance another several mm
40. No
41. Touch probe detection[?]
42. Error listing
43. Input measurement point data
44. Move to dummy point
45. Data processing
46. Printout
47. Measurement complete
48. Start. Load floppy disk, designate automatic measurement, designate program number and line number
49. Planar correction, axial correction, probe diameter check, probe check
50. Keyboard input

3.6 Simulation (Level 2.3) Detailing

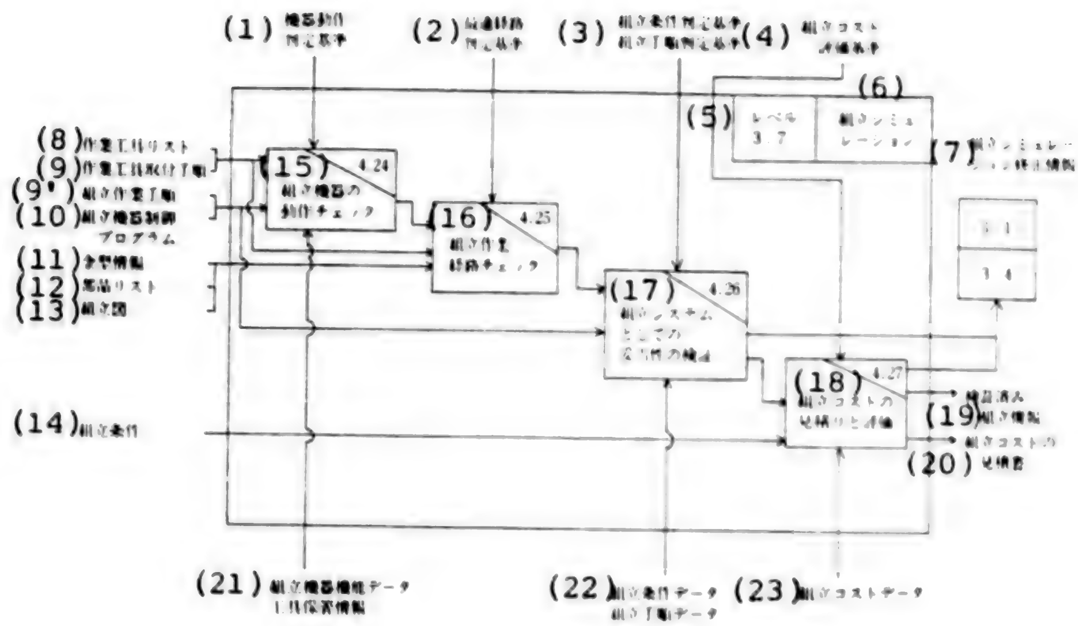
3.6.1 Assembly Simulation (Level 3.7)

As is diagrammed in Figure 3.59, assembly simulation is made up of four processing units, namely assembly equipment operation checking, assembly job route checking, verification of suitability as an assembly system, and assembly cost estimation and evaluation.

Key:

1. Equipment operation judgment criteria
2. Optimum route judgment criteria
3. Assembly condition judgment criteria
   Assembly sequence judgment criteria
4. Assembly cost evaluation criteria
5. Level 3.7
6. Assembly simulation
7. Assembly simulation correctional data
8. Assembly tool lists
9. Job tool attachment sequences
9'. Assembly job sequences
10. Assembly equipment control programs
11. Die data
12. Parts lists
13. Assembly diagrams
14. Assembly conditions
15. Assembly equipment operation checking
16. Assembly job route checking
17. Verification of suitability as assembly system
18. Assembly cost estimation, evaluation

Figure 3.59 Assembly Simulation



19. Verified assembly data 20. Written estimate
21. Assembly equipment function data, tool storage data
22. Assembly condition data, assembly sequence data
23. Assembly cost data

(1) Assembly Equipment Operation Checking (Level 4.24)

(Input)

Job tool lists
Job tool attachment sequences
Assembly job sequences
Assembly equipment control programs

(Output)

Assembly equipment operation verification results

(Reference Data)

Assembly equipment function data
Tool storage data

(Control Data)

Function operation judgment criteria

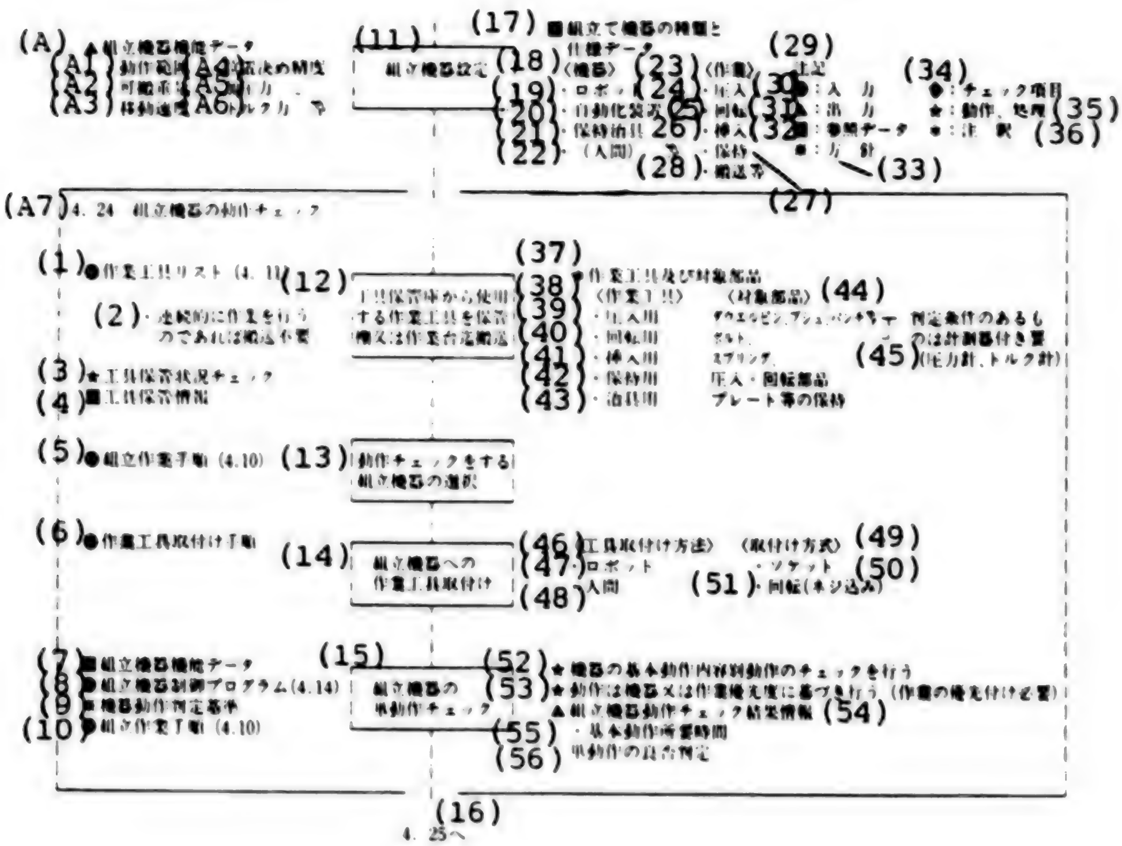
(Processing)

In this processing stage, assembly job sequences, job tool lists, assembly equipment control programs, and job tool attachment sequences are input. Then, following the equipment operation judgment criteria, operation verification data for the assembly equipment are output. During this process, reference is made to assembly equipment function data (ranges of movement, transportable weights, movement speeds, arrival times, positioning precisions, and turning torques, etc.) At this stage, the condition of the tools stored in the tool magazines of the assembly equipment is checked against the job tool lists. If any tool is missing, it is selected from a list of available tools and set in a tool magazine. The assembly equipment is then selected, following the assembly job sequence. The tool storage situation is checked at the same time, and tools are attached according to job tool attachment sequences. Then each basic movement or action of the assembly equipment is checked (press fitting, rotation, holding, transporting, insertion, etc.), and simulation is performed, using basic movement macro instructions and assembly equipment control programs, according to the assembly equipment function data. The checks are made according to the equipment and job priorities, and the merits and demerits of each single movement or action are evaluated according to the equipment operation judgment criteria. A typical flowchart for this operation verification is given in Figure 3.60.

Key:

A. ▲ Assembly equipment function data
A1. • Range of movement A2. • Transportable weight
A3. • Movement speed A4. • Positioning precision
A5. • Pressure force A6. • Torque force, etc.
A7. • Assembly equipment movement check
1. ● Job tool list (4.11)
2. • Transporting unnecessary if doing job continuously
3. • Tool storage condition check
4. • Tool storage data 5. • Assembly job sequence (4.10)
6. • Job tool attachment sequence 7. • Assembly equipment function data
8. • Assembly equipment control program (4.14)
9. • Equipment movement judgment criteria
10. • Assembly job sequence (4.10)
11. Assembly equipment setting
12. Transport job tools to be used from tool storage area to storage shelf or work table
13. Check movement; select assembly equipment
14. Attach job tools to assembly equipment
15. Assembly equipment single-movement check
16. To [level] 4.25

Figure 3.60 Process Flow for Assembly Job Route Checking



17. • Assembly equipment types, specifications
18. <Equipment>
19. • Robot
20. • Automating device
21. • Holding jig
22. • (Human), etc.
23. <Job>
24. • Press fitting
25. • Turning
26. • Insertion
27. • Holding
28. • Transporting, etc.
29. Notes
30. ● : Input
31. ▲ : Output
32. ■ : Reference data
33. ✱ : Guidelines
34. ◆ : Check item
35. ★ : Movement, action, process
36. ＊ : Comment
37. ★ Job tools & relevant parts
38. <Job tool> <Respective part>
39. • For press fitting......Dowel pins, bushings, punches, etc.
40. • For turning............Bolts
41. • For insertion..........Springs
42. • For holding............Press-fitted, turned/rotated parts
43. • For jig................Holding of plates, etc.
44. <Respective part> [included also in item 38 above]
45. Must be equipped with measurement devices when judgment conditions apply (manometers, torque meters, etc.)

46. <Tool attachment method>
47. • Robot
48. • Human
49. <Attachment mode>
50. • Socket
51. • Turning (screwing)
52. * Check each action/motion in each basic operation of equipment
53. * Perform operation according to equipment or job priority (Need to prioritize jobs)
54. ▲ Data resulting from assembly equipment operation check
55. • Time required for basic operation
56. Judge merits/demerits of simple action or operation

(2) Assembly Job Route Checking (Level 4.25)

(Input)

Die data
Parts lists
Assembly diagrams
Assembly equipment control programs
Assembly job sequences
Assembly job conditions
Assembly equipment operation check data

(Output)

Assembly job route check data

(Control Data)

Optimum route judgment criteria

(Processing)

The data input at this stage include die data, parts lists, assembly diagrams, assembly condition data, assembly sequence data, assembly equipment control programs, assembly job sequences, and the assembly equipment operation check data output at level 4.24. Assembly job route check data is output in accord with the optimum route judgment criteria.

In this processing stage, the routes by which assembly parts are transported from the parts storage areas to the work tables are checked against parts lists and assembly sequence data. This checking is based on an assembly equipment control program. Also checked is whether the assembly routes agree with the assembly job sequences. Evaluations are made according to the optimum route judgment criteria. The die assembly order is determined, based on priority rankings such as whether to begin the assembly from the top or bottom. Parts transport is also based on this. When the priority order is the bottom type (the common case), case (b) is better than case (a) attachment in Figure 3.61, but a jig then becomes necessary.

Fig 3.61 Attachment Attitudes in Die Assembly

(a) Vertical (b) Horizontal

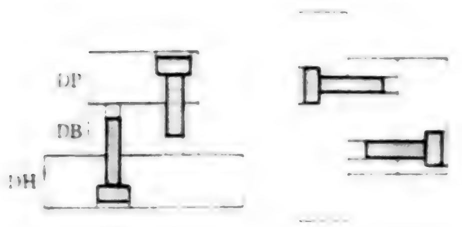
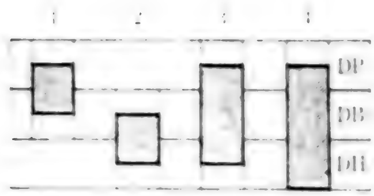


Fig 3.62 Dowel Pin Attachment Data

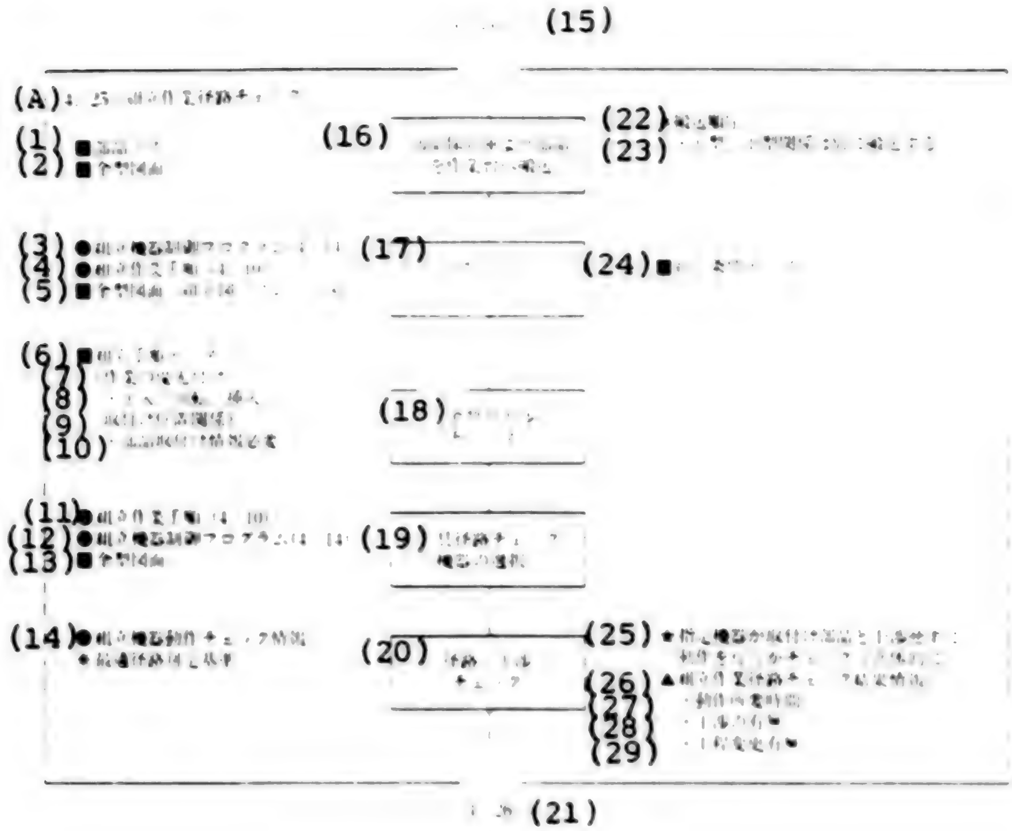


Next, depending on the parts, parts attachment data may be necessary. A case involving dowel pins is diagrammed in Figure 3.62. In the assembly procedures (1) and (2) in the figure, DH and DB are transported, dowel pins are transported and press-fitted, and DP is transported. The assembly condition data include press fitting data (fitting tolerance, pressure force relative to diameter, speed, and press-fitting depth) and turning data (tightening torque force for part and diameter). Then the equipment is selected for the tool movement and an interference check is made. In the interference check, a three-dimensional check is made to see that the equipment in view can move properly without interfering with the attached parts. The routes are checked against the optimum route judgment criteria to determine whether or not it is necessary to modify the procedures. This process is flowcharted in Figure 3.63.

Key:

A. 4.25 Assembly job route check
1. • Parts list 2. • Die drawings
3. • Assembly equipment control program (4.14)
4. • Assembly job sequence (4.10)
5. • die drawings (assembly diagrams, plate diagrams, etc.)
6. • Assembly sequence data 7. <Job prioritizing>
8. • Press fitting, turning, insertion
9. <Attachment position relationship>
10. • Parts attachment data required
11. • Assembly job sequence (4.10)
12. • Assembly equipment control program (4.14)
13. • Die drawings
14. • Assembly equipment operation check data
◆ Optimum route judgment criteria
15. From 4.25
16. Transport parts from parts storage area to work table
17. Die assembly 18. Die interference check
19. Tool route check, equipment selection
20. Route, interference check 21. To 4.26

Figure 3.63 Assembly Equipment Operation Check Process Flow



22. * Transporting order
23. • Transport [parts] relating to upper die and lower die separately
24. • Assembly condition data
25. * Check (three-dimensionally) to insure that designated equipment does not interfere with attached parts
26. ▲ Data resulting from assembly job route check(s)
27. • Time required for movement/operation
28. • Interference (yes/no)   29. • Procedure modification (yes/no)

(3) Verification of Suitability of Assembly System (Level 4.26)

(Input)

Assembly job sequences
Assembly equipment control programs
Assembly job route check data

(Output)

Verified data on suitability of assembly system (time required for assembly, assembly equipment load conditions, etc.)

(Control Data)

Assembly conditions judgment criteria
Assembly sequence judgment criteria

(Processing)

In this processing stage, the suitability of the assembly system is verified. The verification categories include the time required for assembly and the loading on and operating rate for the assembly equipment. By evaluating these categories on the basis of the criteria for assembly conditions and assembly sequences, the merits/demerits of the assembly job sequences can be verified. Should irregularities turn up as a result, data is output and fed back to level 3.1 or 3.4.

(4) Assembly Cost Estimation, Evaluation (Level 4.27)

(Input)

Assembly conditions
Assembly system verification results

(Reference Data)

Assembly cost data (fees charged for each piece of equipment per unit time, labor costs per unit time, etc.)

(Output)

Fully verified assembly data
Written assembly cost estimates

(Control Data)

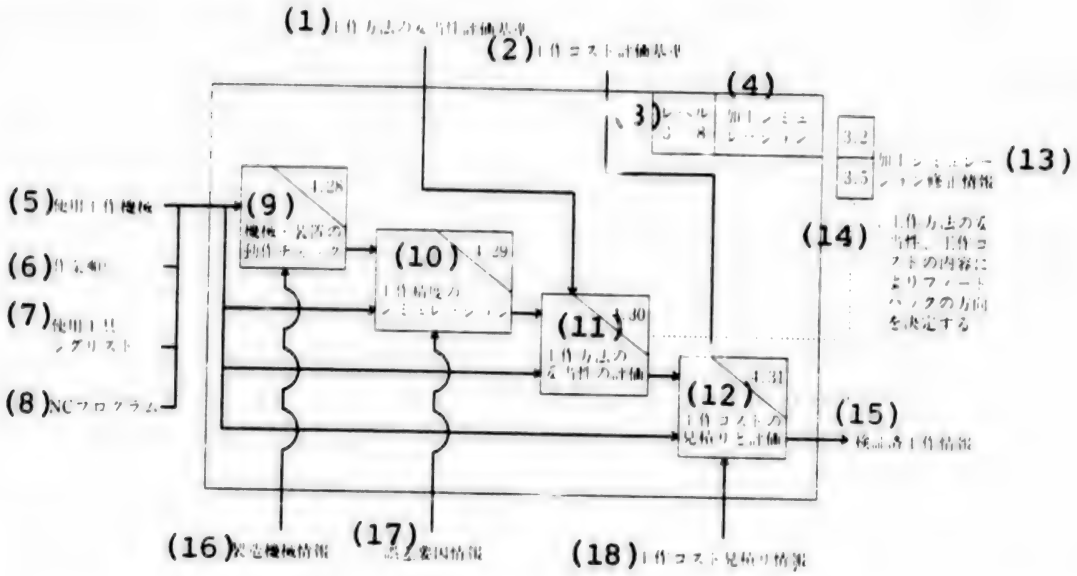
Assembly cost evaluation criteria

(Processing)

In this processing stage, assembly costs are estimated and evaluated. The assembly cost estimates are calculated on the basis of assembly time and the charge structure established for each piece of equipment. These data are output in tabular form. Sometimes, depending on the results of the assembly cost estimates, data are output and fed back to level 3.4.

3.6.2 Process Simulation (Level 3.8)

Figure 3.64 Process Simulation



Key:

1. Fabrication method suitability evaluation criteria
2. Fabrication cost evaluation criteria
3. Level 3.8 4. Process simulation
5. Machine tools used 6. Job sequences
7. List of tools, jigs used 8. NC programs
9. Machine/device operation check
10. Fabrication precision simulation
11. Fabrication method suitability evaluation
12. Fabrication cost estimation, evaluation
13. Process simulation correctional data
14. Determine feedback direction according to suitability of fabrication method and fabrication cost breakdown
15. Fully verified fabrication data
16. Manufacturing machine data 17. Error factor data
18. Fabrication cost estimate data

Process simulation, as diagrammed in Figure 3.64, is made up of four process units, namely machine/device/system-unit operation checking, fabrication precision simulation, fabrication method suitability evaluation, and fabrication cost estimation and evaluation.

(1) Machine/Device Operation Checking (Level 4.28)

(Input)

Job sequences
List of tools, jigs used
NC programs
Machine tools used

(Output)

Fully verified data on operation of machines/devices

(Reference Data)

Manufacturing machine data

(Processing)

In this process stage, based on the job sequences, tools used, jigs attached, and NC program data, the way in which the material being processed is changed by the processing/machining operation is verified, and the possibility of interference between tools, work, and attached hardware is checked prior to actual cutting. There are many methods for fabricating dies. The method in view here is that in which NC machining equipment such as a machining center is used.

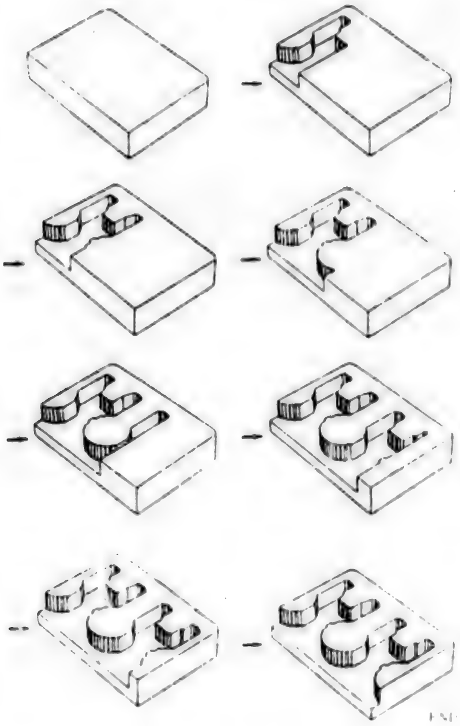
One type of process simulation is shape-change simulation. In order to accurately verify shape changes, changes in shape and surface condition during processing, in the transformation that proceeds from stock material to finished product, are represented sequentially inside a computer, and judgments are made using shape models and Boolean functions. The merits/demerits of tool operation, interference zones, and cutting remainder zones are verified, and checks are made to insure that no problems exist with the fabrication methods, sequences, tools used, or attached hardware. Depending on these results, data may be output and fed back to level 3.2 or 3.5.

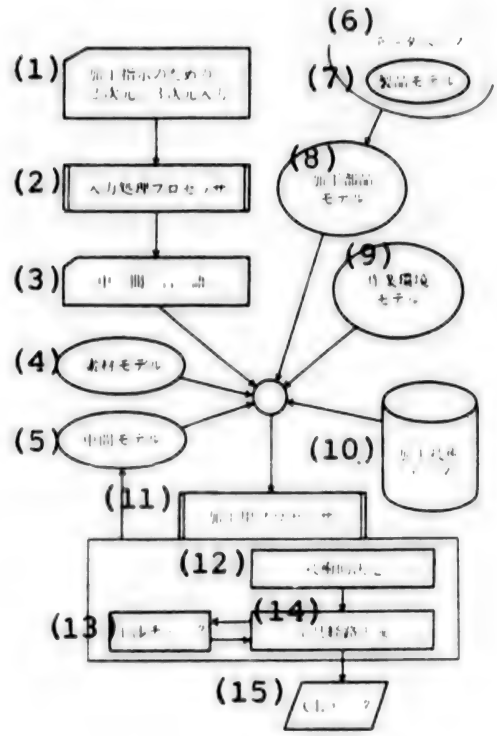
Key to Figure 3.66:

1. 2-D, 3-D input for process designation
2. Input processor
3. Intermediate language
4. Stock material model
5. Intermediate model
6. Database
7. Product model
8. Processed part model
9. Job/work circulation model
10. Process/machining technology data
11. Process-oriented processor
12. Technical determination
13. Interference check
14. Tool route generation
15. CL data

Fig 3.65 Shape-Change Simulation

Fig 3.66 Outline of Software System for Mold Base Processing/Machining





Functions such as those described below are needed in the computerized model for the operations handled here.

1) Processed/machined parts models (finished product models): Models which represent the finished condition of parts to be manufactured

2) Intermediate models: Models which represent the condition of work as it is processed, changing from stock material to finished product

3) Stock material models

4) Job environment models: Models which represent equipment surrounding the work, such as jigs, tool holders, machine tools

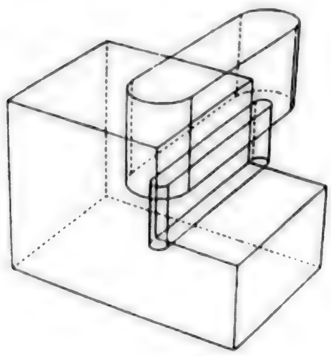
For these models, it is necessary to use three-dimensional surface or solid models.

The data and functions required for these process operations and work include environmental data on jigs, etc., and functions for modeling them. An outline of an example system for these operations is diagrammed in Figure 3.66.

In running checks on interference between and the relative movement of machines, jigs, and tools, on the one hand, and the work, on the other, the data input include job sequences, tools and jigs used, and NC programs. This operation is done concurrently with the verification operation described above. Hence interference between tools and work or attached hardware is checked for prior to actual cutting. In Figure 3.67 are diagrammed examples of checks for interference between tools and work, or tools, machine, and work, in which Boolean functions are employed.

Fig 3.67 Examples of Interference During Cutting Operation

(a) Between Tool Holder, Work



(b) Between Tool, Work

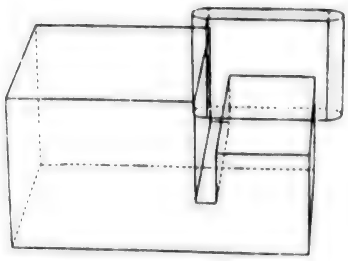
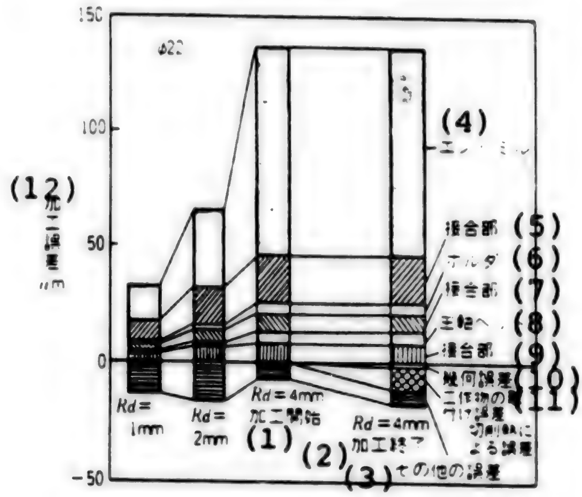


Fig 3.68 Fabrication Precision Error Factors Using an End Mill



Key to Figure 3.68:

1. Processing/machining start
2. Processing/machining end
3. Other errors
4. End mill
5. Joint or connection
6. Holder
7. Joint or connection
8. Main shaft head
9. Joint or connection
10. Geometrical error
11. Work attachment error
12. Processing/machining error

(2) Fabrication Precision Simulation (Level 4.29)

(Input)

Job sequences
List of tools used

NC programs
Fully verified data on machine/device operation
Precision verification locations

(Output)

Fully verified fabrication precision results
Data on shape precision, surface roughness at verification locations

(Reference Data)

Error factor data

(Processing)

The data input here include job sequences, lists of tools used, NC programs, fully verified data on machines/devices (tool operation merits/demerits judgment data), and interference region and cutting remainder data. Priority ranking determinations will be made for precision verification locations and processing/machining precision error analysis. At the same time, analyses are made of transformations and tools, work, and jigs resulting from cutting forces.

Fabrication precision error factors include cutting forces, heat resulting from cutting, and rigidity of machines, jigs, and processed parts.

In this processing stage, when minute precision transformation forecasts are made during processing for all of these error factors, the computation volume becomes enormous. For this reason, these forecasts are first made for important precision points and hazardous locations, such as points of weak strength or places where there is a large change in the direction of cutter movement. Error factor priority rankings are determined experimentally or by using artificial intelligence (AI). Judgments are also made concerning fabrication precision, and transformation amounts are analyzed.

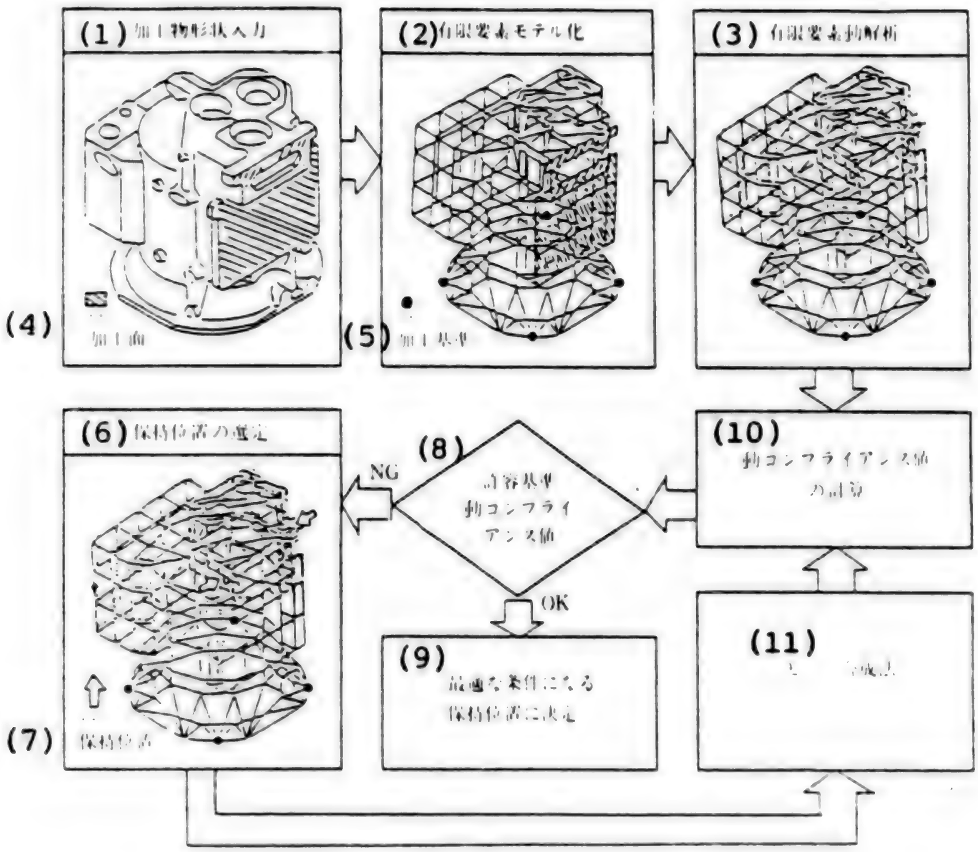
In determining the error factors necessary for precision analysis, error factor data for fabrication precision are prioritized to produce reference data, as diagrammed in Figure 3.68.

In analyzing transformations in tools, work, and jigs caused by changes in forces during cutting, cutting resistance values are derived from combinations of such data as cutting conditions, composition of materials cut or tooled, tool shapes, and cutting fluids. Based on these data, the shape changes within flexibility limits are analyzed and the parts shape precision is verified.

Up until now, this type of analysis has been modeled as separate tasks. For example, structural analysis methods[3,6] have been developed to determine work clamping and holding positions, giving due consideration to the

characteristics of the work/jig system (Cf. Figure 3.69). These methods may also be used to evaluate jig characteristics and maximum cutting capabilities.

Figure 3.69 Example of Jig Designing System Based on Structural Analysis



Key:

1. Input work shape
2. Limited factor model
3. Limited factor dynamic analysis
4. Machined surface
5. Machining reference
6. Selection of holding position
7. Holding position
8. Tolerance criteria, dynamic compliance values
9. Determine holding position to obtain best conditions
10. Compute dynamic compliance values
11. Mode synthesizing method

In analyzing tool and stock material transformations caused by cutting heat, it is currently difficult to predict cutting heats giving due consideration to cutting conditions, tool and material composition, tool shapes, and cutting fluids.

At this point, using values from previous experiments and test data, the thermal expansion of tools and materials is analyzed and judgments are made concerning shape precision. Taking the example of prolonged finishing and cutting operations using an end mill, there are cases in which variations appear in the surface of the dies due to the end mill extending in the axial direction.

In die processing/machining, one thing that can reduce the fabrication precision is thermal deformation caused by accumulations of cuttings. In order to calculate thermal deformation for machine tools/work systems, we need to have formulas for estimating thermal conduction rates for cuttings and contact thermal resistance. The data needed for this analysis are retrieved from a database in making judgments concerning shape changes. One proposed method of analyzing thermal deformation in machine tool/material systems due to accumulated cuttings is represented in Figure 3.70.[3.2]

Figure 3.70 Example Computations of Apparent Heat Conductivity for Cuttings

Apparent Coefficient of Thermal Conductivity for Cuttings:

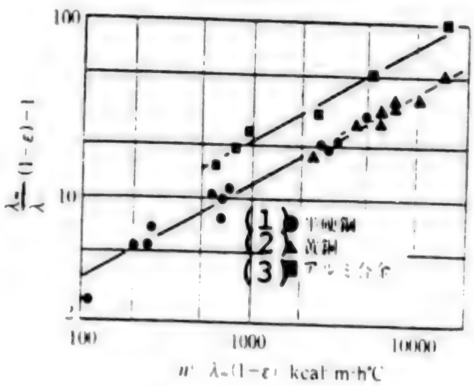
$$\lambda_{eq} = \frac{\lambda_m(1-\varepsilon)}{1+C[n^{1/3}\lambda_m-(1-\varepsilon)]^a}$$

Contact Thermal Resistance for Cuttings:

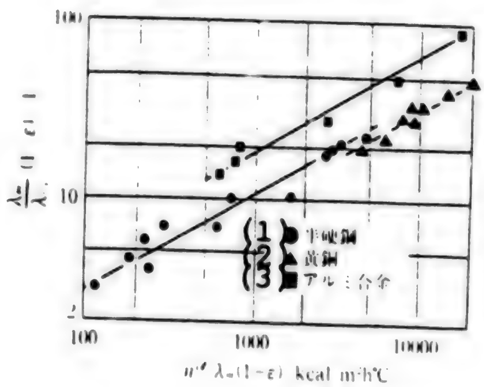
$$R_c \doteqdot C[n^{1/3}\lambda_m(1-\varepsilon)]^{a-1}$$

where λ - coeff of thermal conductivity for cuttings
ε - porosity [or "void ratio"]
v - cuttings volume
w - cuttings weight
γ - spec wt of cuttings
n - number cuttings per unit vol
a - a constant
C - a constant

(a) Dry Condition



(b) Containing Oil



(4)

Key:

1. • Semihard steel 2. ▲ Brass 3. ▪ Aluminum alloy
4. •, ▲, and ▪ represent experimental values

(3) Evaluation of Fabrication Method Suitability (Level 4.30)

(Input)

Job sequences
List of tools used
NC programs
Fully verified data on fabrication precision (precision levels obtainable, verification locations)
Machine tools used

(Output)

Fully verified data on fabrication methods
Fully verified data on job methods, job sequences
Fully verified data on processing/machining methods, order

(Control Data)

Fabrication method suitability evaluation criteria

(Processing)

The data input at this stage include job order, lists of tools used, NC programs, and fully verified data on fabrication precision. Then, following the fabrication method suitability evaluation criteria, the capabilities of and restrictions on the machine tools used are checked, and the suitability of machine tool operating rate ranges, and maximum and minimum ranges for feed and main shaft speed, are evaluated. Depending on the precision results obtained at level 4.29 and the verification location data, correctional data may also be output and fed back.

(4) Fabrication Cost Estimation, Evaluation (Level 4.31)

(Input)

Job order
List of tools used
NC programs
Fully verified data on fabrication methods

(Output)

Fully verified fabrication data

(Reference Data)

Fabrication cost estimates

(Control Data)

Fabrication cost evaluation criteria

(Processing)

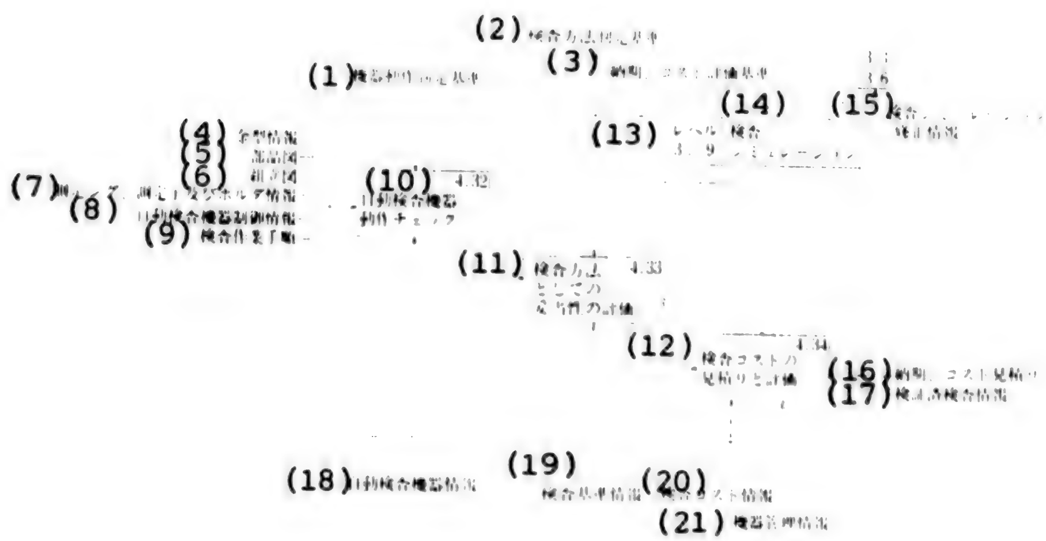
The fabrication cost estimates are based on such data as job order, tools used, number of fabrications, and jig machine tools. In both the fabrication cost estimates and processing/machining precision evaluations, optimum calculations for each purpose are compared with evaluation criteria values.

Depending on the results of the fabrication cost estimates, correctional data may be output and fed back to either the level-3.2 process procedure design or level-3.5 process job design stages.

3.6.3 Inspection Simulation (Level 3.9)

As diagrammed in Figure 3.71, inspection simulation is made up of three process units, namely automatic inspection equipment operation checking, inspection method suitability checking, and inspection cost analysis (estimation and evaluation).

Figure 3.71 Inspection Simulation (Level 3.9)



Key:

1. Equipment operation judgment criteria
2. Inspection method judgment criteria
3. Delivery, cost evaluation criteria
4. Die data
5. Parts drawings
6. Assembly diagrams
7. Data on measurement jigs, probes, and holders
8. Automatic inspection equipment control data
9. Inspection job sequences
10. Automatic inspection equipment operation check
11. Inspection method suitability evaluation
12. Inspection cost analysis
13. Level 3.9
14. Inspection simulation
15. Inspection simulation correctional data
16. Delivery, cost estimates
17. Fully verified inspection data
18. Automatic inspection equipment data
19. Inspection criteria data
20. Inspection cost data
21. Equipment control data

(1) Automatic Inspection Equipment Operation Checking (Level 4.32)

(Input)

Die data
Parts drawings
Assembly diagrams
Inspection job sequences
Measurement jig, probe, and holder data
Automatic inspection equipment control data

(Output)

Equipment operation check data
Inspection categories, time required for measurements

(Reference Data)

Automatic inspection equipment data

(Control Data)

Equipment operation judgment criteria

(Processing)

In automatic inspection equipment operation checking, precision guarantee checks are made on the main inspection equipment units and interference checks are made for measurement probes, movement routes, work being measured, and jigs.

The first thing that is done at this stage is to make a precision guarantee check on the measuring instruments. Measuring instruments are properly zeroed, for example, and calibrations are performed according to [the data listed on] the check plates. In making these determinations, the automatic inspection equipment data (on automatic inspection equipment, optional functions, calibration equipment, measurement probes, inspection jigs, etc.) are employed as reference data. Accordingly, calibration techniques are standardized for each measurement category and precision ranking.

Then, based on the input data, checks are run on the items being measured, jigs, main and auxiliary measuring instruments, on the possibility of interference along the movement routes for measurement jigs, measurement probes, holders, and arms, etc., and on light route interruption. Fully verified equipment operation data are output. The measurement times are also calculated and output. Should any irregularities arise during this processing, correctional data are output and fed back to either the level-3.3 inspection procedure design or level-3.6 inspection job design stages.

(2) Inspection Method Suitability Evaluation (Level 4.33)

(Input)

Fully verified equipment operation data
Inspection job sequences
Inspection categories, measuring times

(Output)

Fully verified suitability evaluation data

(Reference Data)

Inspection criteria

(Control Data)

Inspection method judgment criteria

(Processing)

The evaluation of inspection method suitability entails the evaluation of measurement precision and inspection methods.

In determining the suitability of these inspection methods, fully verified precision guarantee data, interference check data, and the fully verified equipment operation data obtained at level 3.2 are input, and the suitability is evaluated with reference to the inspection criteria. Should irregularities arise, correctional data may be output and fed back to either level-3.3 inspection procedure design or level-3.6 inspection job design.

(3) Inspection Cost Estimation, Evaluation (Level 4.34)

(Input)

Fully verified equipment operation data
Fully evaluated suitability data
Inspection categories, measuring times

(Output)

Delivery, cost estimates
Fully verified inspection data

(Reference Data)

Inspection date and cost data
Equipment control data

(Control Data)

Delivery, cost evaluation criteria

(Processing)

In estimating and evaluating inspection costs, the data input include inspection categories, times required for measurement, and fully evaluated suitability data. Inspection costs are then estimated and evaluated with reference to inspection cost data and equipment control data.

In compiling the inspection cost data, it is necessary to establish standard job times and standard units for each inspection category.

The data output include inspection and delivery estimates, cost estimates, and fully verified inspection data.

Should irregularities arise in estimating and evaluating inspection costs, correctional data are output and fed back either to the level-3.3 inspection procedure design or level-3.6 inspection job design stage.

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3.7 Ito and Iwata: *Furekishiburu Seisan Shisutemu*, Nikkan Kogyo Shimbun-sha, p 143, 1984.

4. Observations & Commentary

A number of CAM systems for die assembly, processing/machining, and inspection have been developed and marketed which focus primarily on processing/machining. These include both DNC systems and FMS. These systems have limited capabilities. They merely access databases containing shape data or graphic data produced on a CAD system, create NC programs for machining/processing with the intervention of skilled workers, and automate the machining/processing operation based on these NC programs. In these systems, in other words, there is almost no automation of such machining/processing preparatory work as procedure design or job design, which are upstream of actual machining/processing. The systemization of assembly and inspection operations is a task yet to be done, moreover, and the technological organization and structuring being done is not necessarily adequate.

In this chapter we summarize, category by category, the results of studies done on problems elucidated during the course of graphic development operations.

(1) Reevaluation of Procedure Design and Job Design Processes

In terms of the main procedure flow in manufacturing, operations are performed in the order of machining/processing, assembly, and inspection. Conventionally, procedure design and job design have been performed in a corresponding order. However, in machine/process procedure design, depending on the assembly precision, it is possible that more machining/processing will have to be done after either partial or complete assembly. For this reason, in machine/process procedure design, it becomes necessary to use assembly procedure data as input data. In machine/process procedure design, moreover, when determining machining/processing reference surfaces or attachment surfaces, a need to employ assembly data arises. For these reasons, in this report, we have made the processing order in procedure design and job design that of assembly, machining/processing, and inspection. Nevertheless, more study still needs to be done on this matter of order.

(2) Shape Division, Machining/Processing Method Assignment

Among the machining/processing methods for forming dies using plastics, die-casting, forging, and press molding, there are cutting, electrical discharge, and electrolytic machining methods, which are used depending on the

shapes involved. Ordinarily, when machining/processing dies, the process shape is broken down into components, and the most suitable machining/processing method is used for each component. In order to automatically determine this machining/processing method, methods must be established for extracting and automatically assigning characteristics according to computer-based die-shape data models. In this report, however, we deal exclusively with manufacturing techniques as used in manufacturing procedures. Excluded, therefore, is any discussion of such software techniques as shape characteristic extraction or shape breakdown. Such data are processed as that which can be obtained when necessary. For this reason, before setting up a CAM system based on our specifications, these software techniques and other peripheral technology must first be established.

(3) Ideal Solutions and Simulation

In drafting these specifications, we worked out solutions for each processing block, based on such control data as evaluation criteria. These solutions were then used in subsequent processing as input data. Furthermore, when irregularities developed in subsequent processing blocks, even when they involved ideal solutions determined in early processing, correctional data were output at that processing block stage and fed back to the earlier processing block. Accordingly, ideal completed programs were already being derived at the level-3.5 control-program drafting stage, and we studied the necessity for simulation based on control programs therefor. As a result, it is not possible at this stage to use, in actual jobs, the NC programs created with the CAM system with 100% dependability. We have reached the conclusion that it is necessary to test and evaluate completed NC programs using simulation. If complete and ideal systems are built, then this simulation function should in future become unnecessary.

(4) Problems in Displaying Feedback Data

In this report, the destination of all feedback in the expanded blocks has been clearly identified. When feedback data are output from one expanded block and directed to another expanded block, however, they are displayed in the destination expanded block. No display is made of data up to the detailed block names for that expanded block, and these are not identified. Nor are the actual particulars of feedback data identified. Such identification is a large task which has yet to be done.

(5) Problems of Graphic Expansions for Assembly, Inspection

Systems such as DNC systems and FMS have already been developed which automate die fabrication, and these provided some degree of preliminary knowledge as we set about to devise these specifications. However, there was no existing automating system to provide helpful information in the areas of die assembly and inspection. For this reason, we believe that the details of these specifications require further study.

5. Afterword

We extracted functions for a die-oriented CAM system, and made graphic expansions in which these functions are detailed, following the processing flow. In this research we analyzed actual die production processes, identifying the flow for each process as well as the necessary input and output data for each process. This was done assuming an ideal production system in which a computer is used. Accordingly, the primary function of this CAM application is to take the product data output by a die CAD system and produce control programs to drive and control machines, devices, and system units to actually manufacture the product. For this reason, the functions demanded in the CAM system are expanded to match the level of automation in the production system.

Large tasks like ahead in developing CAD/CAM systems, namely improving their functions and performance, making them more intelligent, and integrating the CAD and CAM functions. We will be most gratified if this report provides helpful information in achieving these tasks as integrated CAD/CAM systems are developed and brought on line.

This research was carried out by technicians working in public testing and research institutions to improve the functions of CAD/CAM systems and make them more widely used. These people held many discussions on common themes, seeking to establish software techniques for production systems.

This report is the second of a two-part series which began with "Die CAD System Function Specifications." With the completion of this report, entitled "Die CAM System Function Specifications," we think that we have provided an ideal configuration for an integrated CAD/CAM system. We hope that such an integrated system will soon be actually implemented.

These materials are the result of work done in more than twenty meetings in various blocks (Hokkaido•Tohoku, Chubu, Hokuriku, Kinki, Chugoku•Shikoku), but primarily in working groups of the Kantokoshinessei block, following the decision at the 6'th CAD/CAM Research Society to do CAM research. We wish here to express our sincere appreciation to all those who cooperated in this project.

We conclude by noting briefly the activities done in each block and working group.

1. Activities & Studies Pertaining to This Research Done in CAD/CAM Research Society Working Groups

(1) 12'th Working Group (4/22/85)

Finished work on drafting of "Die CAD System Function Specifications." Future activities of the research society were discussed. Many favored taking up the theme of CAM outlook, and this was proposed to the society.

(2) 13'th Working Group (7/16/85)

Discussed CAM guidelines. Agreed to submit proposals on CAM subjects by next meeting.

(3) 14'th Working Group (9/10/85)

Each member explained his or her CAM fields. As to format, it was decided to go with the CAD procedures. Tokyo, Nagano, and Shizuoka had put CAM proposals together, and it was decided to use these as a basis for further research.

(4) 15'th Working Group (10/7/85)

The following consensus was obtained concerning the range of CAM function specifications. While being software-intensive, [the specifications] would be viewed over a wide range, with adequate regard given to physical distribution or flow, and the profile of a futuristic production system would be clearly identified.

(5) 16'th Working Group (12/23/85)

Job proposals submitted by members were discussed, and the major concepts relating to CAM systems were given standard definitions. It was decided that each member would present a CAM system scope, together with extracted problems, at the next meeting.

(6) 17'th Working Group (1/23/86)

CAM system graphic extension proposals were presented by the various members. As to the CAM system scope, only data pertaining to the production processes would be handled, and physical distribution would not be included. However, it was decided that the actual fabrication process would be converted to an idealized production mode, and that data would be given a correspondence to that idealized production mode. The entire production process (level 1) was studied.

(7) 18'th Working Group (2/27/86)

Vertically and horizontally structured proposals were studied for the representation of the entire production process (level 1). As a result, it was decided that the entire process would be described in the form of the vertically structured proposal to which feedback data are added.

Then (level 2) was studied. Procedure design, job design, and simulation were each detailed in blocks holding assembly, machining/processing, and inspection, respectively. Then assembly procedure design, assembly job design, and assembly simulation were detailed (level 3).

(8) 19'th Working Group (4/23/86)

Inspection procedure design, inspection job design, and inspection simulation (level 3) were studied.

(9) 20'th Working Group (5/16/86)

Machining/processing procedure design, machining/processing job design, and machining/processing simulation (level 3) were studied.

(10) 21'st Working Group (7/4/86)

The necessity of making the content of the CAM function specifications specific was argued. A decision was made to take three blocks from level 3 and clearly identify the content and processes of input, output, and reference data. A proposal was to be submitted by the next meeting.

(11) 22'nd Working Group (9/4/86)

The proposal was taken up and discussed by various sub-groups.

(12) 23'rd Working Group (10/2/86)

Work continued to be done in the sub-groups. The future work schedule for the CAM function specifications was discussed, and it was decided to ask the various regional blocks to study the subject of detailing, as follows.

Hokkaido•Tohoku block	Level 3.1
Chubu block	Level 3.4
Hokuriku block	Level 3.7
Kinki block	Level 3.8
Chugoku•Shikoku block	Level 3.9

(13) 24'th Working Group (12/5/86)

A format was determined for representing CAM function specifications. It was also decided to stop the level detailing at level 3.

(14) 25'th Working Group (2/12/87)

With respect to shaping the CAM function specifications, the problems with the SADT procedures were discussed. It was decided that the SADT problems would be dealt with either in a preface or prologue. Questions from various regional blocks were also discussed and responded to.

(15) 26'th Working Group (8/25/87)

The group divided into sub-groups and carried on studies.

(16) 27'th Working Group (4/23/87)

Responsibilities for drafting the final die CAM function specifications were determined.

(17) 28'th Working Group (9/24/87)

It was decided that each member would submit a draft of that portion assigned to him or her by the next meeting.

(18) 29'th Working Group (12/8/87)

Revision work was done on the die CAM function specification draft.

(19) 30'th Working Group (1/28/88)

Revision work continued to be done on the specification draft.

(20) 31'st Working Group (4/26/88)

The final revision work was done on the specification draft.

2. Activities & Studies Pertaining to This Research Done in CAD/CAM Research Society, Chubu Regional Chapter

(1) 6'th CAD/CAM Research Society (9/8/87)

A decision was made to wait until the draft of the die CAM function specifications was explained and a format proposed.

(2) 7'th CAD/[CAM] Research Society (3/7/88)

The content of the draft of the die CAM function specifications was explained.

3. Activities & Studies Pertaining to This Research Done in CAD/CAM Research Society, Tokai Block

(1) First Coordinating Conference (1/30/87)

The materials sent were studied, and basic guidelines were deliberated. Examples: Type of die not to be an issue. Data held at each institution to be submitted. Situation at each group [meeting] to be monitored.

(2) Finalization Work (2/10/87)

Level-3 and -4 interim reports (draft) based on the guidelines decided on at the first coordinating conference were forwarded to the Mechanical Engineering Laboratory.

(3) Second Coordinating Conference (4/16/87)

It was verified that the content of the level-3 and -4 interim reports (draft) and of the materials, opinions, and other block data submitted from the various institutions was subjected to a revision operation.

(4) Finalization Work (8/17/87)

The CAM specifications drafted according to the matters confirmed at the second coordinating conference were forwarded to the Mechanical Engineering Laboratory.

(5) Finalization Work (1/7/88)

The CAM specifications drafted according to "Standard Nomenclature" were forwarded to the Mechanical Engineering Laboratory.

- END -

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